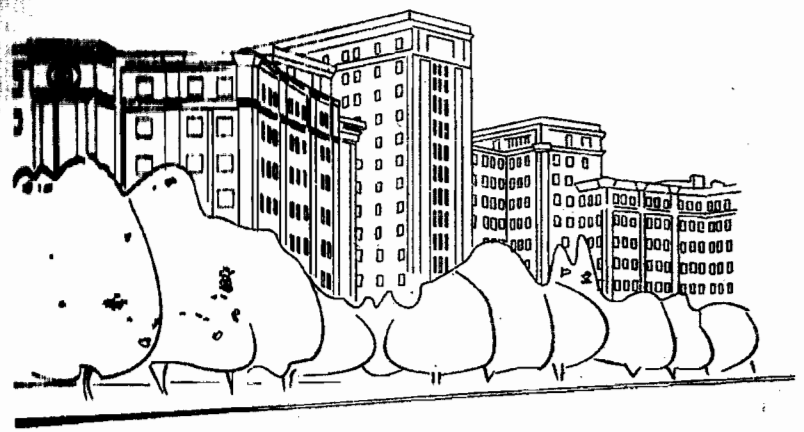
Министерство образования и науки Украины
Харьковский национальный университет
имени В. Н. Каразина

Practice Reading Texts in Biophysics

Учебно-методическое пособие для студентов-биофизиков и медицинских физиков



Харьков 2005

МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ УКРАИНЫ

ХАРЬКОВСКИЙ НАЦИОНАЛЬНЫЙ УНИВЕРСИТЕТ

имени В. Н. КАРАЗИНА

Практикуем чтение текстов по биофизике

Учебно-методическое пособие для студентов-биофизиков и медицинских физиков

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В 76

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Учебно-методическое пособие предназначено для студентов-биофизиков и медицинских физиков старших курсов и аспирантов. Пособие построено на базе оригинальных текстов, которые сопровождаются лексико-грамматическими упражнениями. Пособие может быть использовано как в аудитории, так и для самостоятельного обучения.

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Введение

Данное издание предназначено для студентов-биофизиков и медицинских физиков старших курсов и ставит целью научить студентов читать оригинальную литературу по специальности, извлекая при этом необходимую информацию, и расширяя свои знания в области биофизики, а также оформлять полученную информацию в виде аннотации, достичь определенного уровня владения устной речью, позволяющего вести беседы по специальности и высказывать свое мнение о прочитанном.

Отличительной особенностью настоящего пособия является то, что оно построено на базе учебного материала, изучаемого студентами-биофизиками старших курсов, что позволяет эффективно усваивать содержание текстов на английском языке и развивать навыки иноязычного говорения и ведения дискуссии.

Учебно-методическое пособие включает четыре раздела: Часть I, Часть II и Приложение 1, 2. Части I, II содержат оригинальные тексты по биофизике и снабжены системой послетекстовых упражнений, целью которых является преодоление лексико-грамматических трудностей, формирование навыков чтения и говорения по специальности. Приложение 1 содержит необходимые речевые образцы для формирования навыков аннотирования и реферирования прочитанного. Приложение 2 включает в себя образцы прочтения математических знаков, символов и уравнений, химических элементов и формул на английском языке.

Материалы пособия рекомендуется использовать следующим образом:

- Ознакомиться с содержанием текста в процессе самостоятельной работы с использованием словаря,
- выполнить систему послетекстовых упражнений по лексико-грамматической обработке текста и выделению основной информации,
- ответить на предлагаемые вопросы к тексту,
- выразить свое отношение к прочитанной информации,
- выполнить задание по логической обработке текста (план, аннотация, реферат, пересказ).
- в случае возникновения трудностей при аннотировании и пересказе текстов целесообразно использовать материалы, приведенные в Приложении 1.

Пособие может использоваться как для аудиторной, так и для самостоятельной работы студентов.

Part I

Biomembrane Models

Pre-reading task

Answer the following questions

1. What are membranes?
2. What have you already known about their functions?

Text 1. Introduction: Existence and Composition of Biomembranes

Contemporary discussions of biomembrane models are based on two assumptions: first that membranes do indeed exist in vivo, and second that they can be isolated relatively intact and characterized chemically. The first assumption, that the living cell is physically separated from its environment by an ordered array of molecules, has received extensive physiological and morphological confirmation over the past 80 years. For example, permeability has been examined since the late 1800's; cells were observed to shrink or swell in response to the tonicity of their environment, behaving as tiny osmometers, and such shape and size changes could be modulated by the addition of nonpolar molecules. The simplest physical explanation was that cells were delimited by a semipermeable, nonpolar membrane. Structural support for the membrane concept came from early electron microscope studies; a distinct trilaminar staining pattern was evident at every cell's periphery.

Although early attempts to isolate chemically pure fractions of membranes were subject to criticism, they provided an indication of the gross composition of biomembranes. With few exceptions, all membranes contain protein plus various amounts of lipid and often small amounts of carbohydrate. Proteins usually constitute from 25% to 75% of the membrane by weight, lipids from 75% to 25% respectively, and carbohydrates usually less than 10% by weight. All biomembrane models that attempt to provide a common denominator arrangement of these components emphasize the role of the compositionally dominant molecules: proteins and lipids.

The majority of model builders additionally assume that all membranes have certain structural features in common. This assumption underlies the following discussion of membrane structure. We begin our discussion with a review of early research, because current models of biomembranes incorporate fundamental features

of earlier proposals. It should be emphasized, however, that models are often built to be compatible with a collection of observations which by themselves are inconclusive.

I. Match the definitions with the words given below.

a) to become smaller, e. g. from heat, cold etc.
b) to form the basis of (a theory, doctrine)
c) to cause to increase in volume, size, etc.
d) to change itself forming an integral part of the composition
e) to place apart and along
f) the part of a fraction written below the numerator
g) something taken for granted.

denominator, to shrink, assumption, to swell, to modulate, to underlie, to isolate

II. Find some pairs of synonyms in the text.

III. Answer the following questions.

1. What are modern discussions of biomembrane models based on?
2. What was the simplest physical explanation of permeability?
3. What do all membranes consist of?
4. What do biomembrane models emphasize?
5. All membranes have certain structural features in common, don't they?

IV. Summarize the text orally.

Text 2. Gorter and Grendel, the Lipid Bilayer

Among several possible stable arrangements of protein and lipid molecules in plasma membranes, the bilayer model has dominated for over 50 years. The bilayer proposal is credited to Gorter and Grendel (1925), who compared the surface areas occupied by monomolecular layers of lipids extracted from erythrocytes to the total surface area of the cells. Because the ratio of the area of extracted lipid to area of intact cell was approximately two to one, the authors concluded that the cell was covered by a layer of lipid two molecules thick (**Fig.1**). An important feature of this model was that the hydrophilic groups of the lipids were oriented at the surface of the bilayer and hydrophobic groups at its interior. Although it was later shown that their

lipid extraction was incomplete and their surface area measurements too low, these two errors approximately canceled one another and their conclusion remained unchanged. Better recent determinations have shown that the lipid present is sufficient to cover the surface with more than one but less than two monolayers.

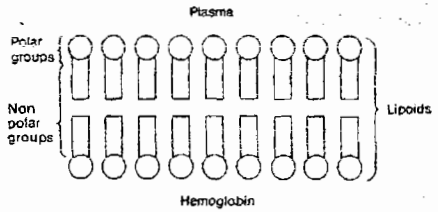


Fig. 1 Diagram of the amphiphilic lipid bilayer as proposed by Gorter and Grendel in 1925. Although they included no such drawing in their short paper, the terms they used to describe the membrane are given here.

I. Fill in the gaps with the appropriate prepositions.

1. An important feature ... this model was that the hydrophilic groups of the lipids were oriented ... the surface of the bilayer and hydro phobic groups ... it interior.
2. Gorter and Grendel compared the surface areas occupied ... monomolecular layers ... lipids extracted ... erythrocytes ... the total surface area of the cells.
3. The lipid present is sufficient to cover the surface ... more than one but less than two monolayers.
4. The bilayer model has dominated ... 50 years.

II. Describe Fig. 1. in detail.

III. Answer the following questions.

1. What kind of biomembrane model has dominated for over 50 years of the 20-th century?
2. What was the main feature of this model?
3. What was thc disadvantage of this model?

Text 3. **The Danielli-Davson-Robertson Model and Other Models**

Subsequent models also based on the lipid bilayer have taken the protein into consideration. One widely discussed early model was that of Danielli and Davson

(1935). Measurements of the surface tensions at lipid-water interfaces yielded significantly higher values than the extremely low values found in living cells.

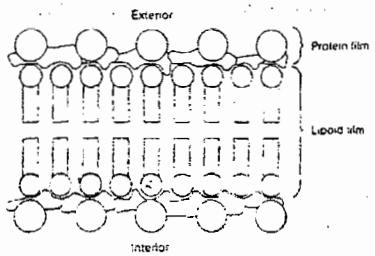


Fig. 2 Diagram of the Danielli and Davson membrane model.

To account for membrane protein, the authors in 1935 placed globular polypeptides at each surface of the lipid bilayer. and then in 1937 added "unrolled" proteins. The descriptive terms are those of Danielli and Davson (2x10-5 Ncm-1). Danielli proposed that protein adsorption to the surface of the lipid films could explain these low values **(Fig. 2)**. Such a model, however, has subsequently been shown to be unlikely. Two arguments against it are that (1) phospholipids alone can produce the low interfacial tension characteristic of native membranes, thus eliminating the necessity for protein adsorption at lipid head groups, and (2) the mass of most membrane protein is so large that its exclusive location at the surface would necessitate total coverage of both surfaces, yet large portions of the membrane lipids are chemically accessible from the aqueous phase. Phospholipids, for example, may be readily degraded by enzymes, and neutral lipids such as cholesterol are freely exchangeable. Summaries of other arguments against the Danielli-Davson-Robertson model have been presented by Stoeckenius and Engelman (1969) and by Singer (1971).

Several nonbilayer models of biomembrane structure have been proposed during the past *50* years. Most were based on evidence derived from studies of intracellular membranes, especially chloroplast thylakoids and the inner mitochondrial membrane. A common feature of the more enduring nonbilayer models is that they propose structural subunits. Because certain physiological properties could be described by assuming functional units of constant composition, it was thought that structural equivalents must also exist. However, no such units, e. g., lipoprotein particles, could form model membranes experimentally or could be isolated from membranes. Moreover, other current data cannot be adequately explained by subunit models. Arguments for and against subunit models have been discussed in the review by

Stoeckenius and Engelman (1969).

I. Make up sentences using the words given below.

1. A, models, more, that, feature, common, is, subunits, of, they, structural, the, nonbilayer, propose, enduring.
2. Yielded, such, measurements, values, than, higher, low, values, significantly, cells, in, living, found, extremely.
3. Values, proposed, to, the, films, surface, Danielli, that, of, lipid, low, explain, protein, could, absorption, the, these.
4. Phase, large, the, lipids, chemically, portions, membrane, are accessible, of, aqueous, the, from.
5. Could, membranes, such, be, particles, units, not, from, lipoprotein, isolated, as.

II. Describe the diagram of the Danielli and Robertson model and compare it to Gorter and Grendel's diagram.

III. Give the answers to the following questions and discuss them with your partner.

1. What did this model take into consideration?
2. What were the arguments against this model?
3. What evidence were nonbilayer models based on?
4. Do they have a common feature?

IV. Give a short summary of the text.

Text 4. Bilayer Model of Lipid Arrangement in Biomembranes

The most appealing argument for the existence of a bilayer in the biological membrane is the intrinsic thermodynamic stability of model bilayers. Bilayer arrangements of amphiphilic lipids represent a minimum energy configuration resulting primarily from the exclusion of the hydrocarbon chains by water molecules (Tanford, 1973). Water molecules at the surface of a nonpolar solute orient to compensate for broken bonds creating a higher degree of local order and thus a decrease in entropy. Removal of the hydrocarbon surfaces from contact with water results in more randomly hydrogen-bonded water molecules, increasing entropy and

producing a favorable free-energy change. Typical amphiphilic membrane lipids spontaneously associate in smectic or lamellar mesophases at hydration greater than 20% Thus the overall pattern proposed for the bilayer is one based on the polar and nonpolar character of its constituent molecules. The hydrophobic portions of the molecules are excluded by water and associate with one another. The polar head groups associate with each other and with the aqueous phase as well.

I. Give antonyms to the following words:

To create, appealing, stability, exclusion, to decrease, randomly, favorable.

II. Answer the questions to the text.

1. What is the main argument for the existence of a bilayer in the biological membrane?
2. What role do water molecules play in bilayer arrangements?
3. What is the total pattern proposed for the bilayer based on?
4. What do the parts of the constituent molecules associate with?

Text 5. Evidence from Model Systems and Biomembranes

The strongest experimental evidence for the existence of a bilayer in biological membranes is derived from the comparison of the properties of biomembranes to the properties of model membranes. A variety of physical and chemical methods have been used for such experiments. Most fall in three categories: electromagnetic (microscopy, diffraction, spectroscopy), thermochemical (calorimetry), and electrochemical (polarography). Microscopy and diffraction have contributed most to our understanding of the static structure of the membrane, whereas spectroscopic and calorimetric methods have been used to probe kinetic aspects.

Early evidence for a palisade arrangement of lipids in biomembranes came from light microscopy and X-ray diffraction studies of nervous tissue. By 1900 polarization microscopy had shown that myelinated nerve fibers were strongly birefringent, indicating a high degree of molecular order. A model of myelin that attempted to explain both its strong positive intrinsic birefringence and its weak negative form birefringence was given by W. J. Schmidt in the mid-1930's. He suggested that the lipids in the sheath were oriented in concentric sheets with their fatty acid chains radially aligned and that protein layers alternated with the lipid layers. This model was strongly supported by low angle X-ray diffraction studies of

F. O. Schmitt and his collaborators. He, too, concluded that the myelin sheath was composed of lipids arranged in smectic mesomorphic leaflets, and postulated that cell membranes had the same basic structure.

Transmission electron microscopy (TEM) confirmed ;that the myelin sheath was indeed derived from the plasma membrane. Moreover, thin-sectioning techniques convincingly showed that the plasma membrane was consistently found on the surface of the cytoplasm of all cells. Most importantly, TEM also revealed that the cytoplasmic compartment also contained many membranes. In thin section both plasma and intracellular membranes had the same overall features: an electron-transparent space delineated by two electron-scattering, dark lines representing sites of heavy metal accumulation. The ubiquity of this trilaminar structure was demonstrated by J. D. Robertson (1959) who coined the term "unit membrane." The transparent space was thought to represent the nonpolar portions of the lipid molecules, and was thus consistent with the bilayer model of lipid arrangement (**Fig. 3**). Electron microscopy of model systems consisting of lipid vesicles and multilamellar myelin figures confirmed this interpretation. When the surfaces of these structures were coated with protein, their TEM images closely resembled those of cell membranes.

Fig. 3 Electron micrograph of two membranes of the rat intestine, chemically stained with heavy metals and thin-sectioned, shows the typical trilaminar structure — dark line, light space, dark line —on which Robertson (1959) based his "unit membrane" hypothesis. Magnification × 400.000)

Later, freeze-fracture techniques produced results which also supported the bilayer model. In this method biological samples are rapidly frozen, fractured, sometimes etched (volatile molecules, mainly water, sublimed in vacuole), shadowed with heavy metal under vacuum, and the replicas examined by TEM. D. Branton and R. Park suggested in the mid-1960's that during freeze-fracture the biological membrane "splits" between the methyl end groups of lipids, i.e., in the central plane of the bilayer. This suggestion has been repeatedly confirmed. Since the vast majority of biomembranes split along an internal plane, the freeze-fracture method provides the

strongest evidence for the ubiquitous occurrence of a bilayer in biomembranes (**Fig.4**).

Evidence that the structure of biomembranes is based on the bilayer also comes from X-ray diffraction studies of synthetic lipid mixtures and natural membranes. For example, membrane lipids and their synthetic analogs show a variety of temperature- and hydration-dependent packing patterns (e.g., hexagonal, cubic, lamellar) that can be identified by their diffraction patterns. Diffraction from both liposomes and isolated biomembrane preparations clearly shows the lamellar or bilayer arrangement.

X-ray diffraction studies are not only useful for studying the overall arrangement of lipid molecules, but also for gathering information on the packing of the fatty acid chains in the bilayer.

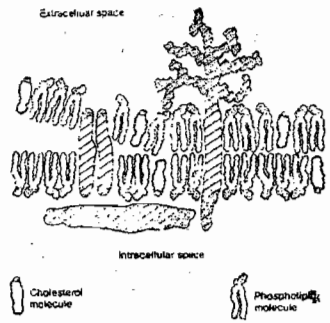


Fig. 4 A diagram of a membrane model based on the "fluid mosaic" model proposed by Singer and Nicolson in 1972. Their model included several features illustrated here. Proteins *cross-hatched)* are either peripherally associated with the bilayer or an integral part of it and capable of translation or rotation. This drawing also illustrates how the lipid bilayer is split (*left*) by freezing and fracturing. The lipids and carbohydrate chains (branched structures attached to the polypeptide backbone, protruding from the extracellular surface) are projections of space-filling molecular models. The transmembrane polypeptides are drawn as approximate helices matched in scale to the lipids (Luzzati, 1968).

The exact physical state of the hydrocarbon chains in membranes and lamellar lipid-water systems has been intensively investigated. Two different structural states are commonly found. In one, below a certain critical or "transition" temperature, the hydrocarbons form a solid phase with stiff extended chains in a hexagonal lattice. In the other, above the critical temperature, they become disordered in a more liquid-like arrangement; their average lateral spacing increases, and the thickness of the

bilayer decreases. This transition from the gel-like ordered phase to the liquid-like disordered phase is characteristic of the bilayer arrangement of lipids.

In biomembranes too, under certain conditions, phase transitions have been observed. For example in an early X-ray diffraction examination of *Mycoplasma laidlawii* membranes. Engelman observed a reversible decrease in hydrocarbon spacing from 0.46 to 0.42 mm upon lowering the temperature, indicative of the phase transition in the bilayer. Using a fatty acid auxotroph strain, he could further show that the temperature at which the transition occurred depended on the fatty acid composition of the membrane lipids. At the time this was the most convincing direct evidence that the lipids in membranes exist in the form of a bilayer. Many similar experiments have since confirmed his conclusion.

I. Define whether the statements below are true or false and correct the false statements.

1. Microscopy and diffraction methods were used to explain the dynamic structure of the membrane.
2. By 1900 polarization microscopy had shown a high degree of molecular order.
3. W. J. Schmidt suggested that the lipids in the sheath were oriented in straight sheets with their fatty acid chains.
4. Figure 4 illustrates how the lipid bilayer is fused by freezing and fracturing.
5. The hydrocarbons from a liquid -- like disordered phase.
6. Engelman observed an increase in hydrocarbon spacing upon lowering the temperature.
7. Engelman showed that the temperature of the transition depended on the fatty acid composition of the membrane lipids.

II. Complete each sentence with words or phrases given below. Mind usage of proper tense-forms.

1. Microscopy and diffraction ... most to our understanding of the statistic structure o the membrane.
2. A model of myelin attempted to explain ... its strong positive intrinsic birefringence ... its weak negative birefringence.
3. TEM .. that the myelin sheath ... the plasma membrane.
4. The ... of this trilaminar structure ... by J. D. Robertson.
5. In this method biological samples ... and ... .
6. The freeze-fracture method provides the strongest ... for the ... of a bilayer in biomembranes.

7. Diffraction from lipocomes and ... biomembrane preparations ... the lamellar or bilayer arrangement.

to contribute, ubiquity, to freeze, evidence, to isolate, to derive from, both ... and, to confirm, to demonstrate, to fracture, ubiquitous occurrence, to show

III. Answer the questions to the text.

1. What evidence proves the existence of a bilayer in biological membranes.
2. What three types of physical and chemical methods have been suggested.
3. What results have been gained?
4. What had polarization microscopy demonstrated by 1000?
5. What model was proposed by Schmidt in the mid. 1930's?
6. What conclusion was drawn by F. O. Schmidt and his collaborators?
7. What did TEM revealed?
8. What did Robertson base his "unite membrane" hypothesis on?
9. What were the results of the freeze-fracture techniques?
10. What do X-ray diffraction studies confirm?
11. Under what conditions do two different structural states of the hydrocarbons chain occur in membranes?
12. What did Engelman's experiments show?

IV. Write a summary on this text.

Text 6. Lipid Class Asymmetry and In-plane Arrangement

Whereas early physicochemical examinations were limited to cataloging the bulk composition and gross structural features of biomembranes. in the 1970's techniques became available to provide more detailed descriptions. Earlier, X-ray diffraction data had already indicated that the structural unit of the myelin sheath has an asymmetric electron density profile. In later studies this was attributed to cholesterol, asymmetrically distributed across the membrane bilayer. Studies of model membrane vesicles by NMR and EPR have also shown numerous cases of asymmetry across the bilayer; the type of lipid in each monolayer can be quite different. The qualitative differences are often explained by the geometrical properties of the molecules (e.g., tapered lipids can fit more easily in the interior monolayer of a small vesicle with high radius of curvature) and by ionic interactions between lipids or with diffuse ionic layers at the hydrophilic interface.

Chemical studies, too, have provided evidence for transmembrane asymmetry of lipid distribution. The general conclusion is that erythrocyte lipids are asymmetrically distributed; phosphatidylethanolamine and phosphatidylserine are predominantly in the cytoplasmic monolayer and phosphatidylcholine and sphingomyelin in the outer monolayer. There is evidence that cholesterol also may be present at higher concentration in the outer monolayer.

Lipid distribution is nonrandom not only across the plane of the membrane but also in the plane of the membrane. For example, phospholipids of a particular class may form clusters within the plane of the membrane or may be preferentially bound to specific proteins. The acyl chains of those lipids proximal to membrane polypeptides may have altered properties relative to bulk phase lipids and as such form a boundary or annulus. This has been shown for lipids that preferentially associate with cytochrome b5 as well as with calcium-dependent ATPase molecules. Even in pure phospholipid bilayers, as a function of temperature, a mixture of ordered and disordered regions can coexist in the plane of the model membrane.

The in-plane distribution in mixed lipid bilayers has been extensively studied. If two classes of phospholipids with different transition temperatures are mixed to form model bilayers, they can produce a mosaic at temperatures between their transition temperatures. The phenomenon is called lateral phase separation. The phospholipids diffuse laterally in the plane of the membrane monolayers, and molecules of the same class associate to form regions that are disordered (lipids above their transition temperature) and ordered (lipids below their transition temperature).

With regard to phase transition phenomena, it should be emphasized that such transitions are most readily documented in synthetic model systems and may or may not play a significant role in natural membranes. These phenomena obviously require mobility of individual molecules within the bilayer, and this aspect will be discussed next.

I. Complete the following sentences according to the information from the text.

1. In the 1970's techniques became available … .
2. Studies of model membrane vesicles have shown … .
3. The general conclusion of chemical studies is … .
4. Phospholipids of a particular class may … .
5. In pure phospholipid bilayers a mixture of ordered and disorded regions can … .
6. Phospholipids with different transition temperature can produce … .
7. Phase transition phenomena require …

II. Make up 10 questions on the text and ask your partner to answer them. Discuss your answers.

III. Write an abstract on the text.

Text 7. Lipid Dynamics

Until the late 1960's bilayer models were often perceived to be static structures. The application of spectroscopic techniques capable of monitoring rapid molecular motion changed our conception of membrane structure. Concomitantly, fluorescence light microscopic methods revealed the mobility of labeled surface receptors, dramatically emphasizing the dynamic aspect of membrane structure.

Motions of lipids can be inferred from their thermochemical behavior. For example, phospholipids in their lamellar phase absorb a constant amount of heat per degree rise in temperature above and below their solid (gel) to fluid (liquid-crystalline) phase transition temperature. When the transition temperature is reached, however, additional heat (3 to 4 cal g-1) is absorbed by the sample. This highly cooperative endothermic transition arises from the sudden increase in motion mainly of the hydrocarbon chains in the hydrophobic bilayer interior when the temperature is raised through the transition region. The thermal properties of biomembranes examined by differential calorimetry or differential thermal analysis mimic the properties of bilayers formed from their isolated lipids or from synthetic lipids. Such similarity in behavior has been used as further evidence supporting the bilayer content of biomembranes.

Spectroscopic methods (EPR, NMR, IR, Raman, fluorescence) have provided substantial information about the motions of amphiphilic molecules. The methods have been used to monitor temperature-dependent transitions of lamellar lipids, and it has been found that signals derived from pure lipid or mixed bilayer systems are similar to those from biological membranes. Spectroscopy can provide detailed information about the motions within individual molecules, as well as their short and long-range interactions. Electron spin resonance techniques especially have had significant impact on our conception of lipid mobility.

EPR, NMR, and fluorescence depolarization have been used extensively to examine intramolecular motion. Signals from labeled fatty acid chains of phospholipids have shown that there is a gradient of flexibility with restricted mobility at the head group and increased rotational freedom toward the terminal methyl groups in the center of the bilayer. The degree of "flexibility" is a function of

the type of lipid, its saturation, chain length and other properties, as well as temperature and solvent characteristics (e.g.. presence of cholesterol generally decreases flexibility).

In pioneering experiments in the late 1960's, Hubbell and McConnell showed that spin labels inserted into synthetic phospholipid vesicles undergo rapid anisotropic motions similar to those found when they are inserted into axonal membranes from lobster. It has also been shown that the rate of rotational diffusion in sarcoplasmic reticulum membranes is rapid (10-8 cm2 s-l) and comparable to that in synthetic phospholipid bilayers. It should be mentioned, however, that biomembranes or membranc fractions can also show limited mobility. In the study by Hubbell and McConnell (1969) rotational spin mobility was found to be much less in erythrocyte membranes. Thus, whereas some membranes such as rod outer segment disc membranes appear to be highly "fluid", others such as erythrocyte membranes are lcss so. Moreover, substantial variation can be found as a function of lipid chain length or saturation, mixed lipid interactions, temperature, pH, ionic strength and other factors.

Most rotational diffusion frequencies derived by EPR, NMR, or optical techniques agree over the range of 107 to 108 s-1. Given certain assumptions, rotational relaxation time can be related to the viscosity of the suspending medium and lateral diffusion rates can be calculated. Such correlations produce values in the range of 1 to 10 P for most biological membranes. Rates of lateral diffusion of lipid can also be determined directly and are found in the range of 10-7 to 10-8 cm2 s-1 for both model phospholipid bilayers and biomembranes. In other words, at room temperature in one second a single molecule can move several micrometers. It should be noted, however, that diffusion constants derived from probc molecules may not accurately reflect the bulk viscosity of the membrane but only local microviscosities.

Movement of amphiphilic lipids from one monolayer of the bilayer to the other has also been assessed by spectroscopic techniques. The process has been called transverse diffusion or "flip-flop" to distinguish it front in-plane translational mobility. Bilayers can be labeled asymmetrically by one-side addition of amphiphilic probes or by symmetric addition coupled with selective quenching of the signal on one side of the membrane To measurc flip-flop, changes in signal amplitude an monitored with time. The conclusion reached by those using fluorescent or spin-labeled lipid analogs is that transmembrane exchange is a relatively slow process for both phospholipids and neutral lipids in pure lipid vesicle systems. The time interval for 50% of the molecules to flip from one monolayer to the other is in the range of hours to days or even weeks. Not only spectroscopic studies but lipid exchange

experiments with synthetic bilayers have also been interpreted in terms of slow-transverse diffusion. Diverse lipids incorporated in synthetic bilayers show two pools of exchange molecules, equilibrates readily with an external sunk and one that exchanges only very slowly, if at all. It has been suggested that this slowly exchanged pool resides in the interior monolayer of the bilayer. Similar results have been obtained by chemical labeling or enzymatic digestion from only one side of the bilayer.

The term "translocation" has been applied to the movement of lipid -molecules across the biological membrane bilayer in contrast to the term flip-flop used for artificial bilayers (Rothman and Lenard, 1977). In natural membranes certain classes of phospholipids and neutral lipids have been found to move rapidly, in seconds or minutes, between the two halves of the bilayer. This translocation presumably requires special mechanisms and may include enzymatic modification of the lipid: for example, the methylation of phosphatidylethanolamine to form phosphatidylcholine.

Thus, the lipid bilayer is a dynamic molecular structure present on the surface of all cells and most cell organelles and its primary function is to restrict permeability to water-soluble ions and molecules. Obviously this permeability barrier has to be modified by incorporation of specific pathways for solutes necessary for cell metabolism and for molecules such as hormone receptors which mediate other specific cellular functions. The lipid bilayer also provides a dynamic framework for the insertion of these components. Such functional differentiations may be mediated by single molecules acting as carriers or by small assemblies of membrane proteins and occasionally by large paracrystalline arrays. Most of these components are proteins, which may interact with specific lipids.

I. Define the following terms using the information from the text.

1. degree of flexibility;
2. substantial variation;
3. translocation;
4. lipid bilayer.

II. Explain in your own words the meaning of the following expressions.
Use them in sentences of your own.

Static structures, labeled surface receptors, endothermic transitions, synthetic lipids, restricted mobility, rotational relaxation time, neutral lipids, artificial bilayers.

III. Answer the following questions.

1. What did fluorescence light microscopic methods reveal?
2. Describe the thermal properties of biomembranes.
3. What can spectroscopy provide?
4. What did the experiments made by Habbell?
5. What correlations produce values in the range of 1 to 10 P for most biomembrane?
6. What are rates of lateral diffusion?
7. Is it possible for diffusion to reflect accurately the bulk viscosity of the membrane?
8. How long may the process of slow transverse diffusion last?
9. What results have been obtained by lipid exchange experiment?
10. What does the process of translocation require?
11. What does the lipid bilayer provide?

Text 8. Models of Protein Arrangement in Biomembranes

All conceivable distributions of membrane proteins in or on membranes have been proposed by various investigators. Membrane proteins have been placed as globular or extended layers at one or both surfaces of the bilayer. They have been portrayed as partially or totally embedded within one or both monolayers, sequestered between the two monolayers. or spanning the thickness of the bilayer with portions exposed at both surfaces. Their interaction with lipids has been thought to be purely electrostatic between charged groups on the protein surface and the lipid head groups, purely hydrophobic with the lipid hydrocarbon chains in contact with hydrophobic regions on the protein surface or penetrating into the protein interior, or combinations thereof. Early proposals cmphasized thc surface location, latcr ones the interior or transmembrane location. A less extreme view, the combination of both concepts has currently gained favor.

Part I. Danielli and Davson, Robertson's "Unit Membrane"

The first attempt to account for membrane protein structurally was that by Danielli and Davson (1935). They placed protein at the surface of the bilayer. Initially in globular form and subsequently in extended pleated sheets (beta conformation). This arrangement was postulated to explain the low interfacial tension found in biological membranes.

In the late 1950's the Danielli-Davson model was given, support by Robertson's

"unit membrane" picture. In a unit membrane (**Fig. 3**) the dark lines are interpreted as being due to the heavy-metal stain bound to the polar groups of the proteins covering the surfaces of the bilayer.

Arguments against the Danielli-Davson-Robertson model have been reviewed by Singer (1971). To restate the salient ones: (1) ORD and CD as well as X-ray and electron diffraction data suggest a substantial alpha-helix content in membrane proteins; (2) the membrane phospholipids are easily hydrolyzed suggesting substantial contact with the aqueous milieu (albeit hydrolysis times are long, allowing for significant rearrangement); (3) transmembrane function becomes difficult to explain if all membrane proteins are located peripheral to the hydrophobic core: (4) extraction experiments, particularly those with chaotropic agents or detergents, suggest substantial hydrophobicity of many purified membrane proteins; (5) the presence of particles on the hydrophobic fracture faces of membranes as revealed by freeze-fracturing can be traced to the presence of proteins; (6) NMR, EPR and related techniques show interaction with lipid hydrocarbon chains when membrane proteins are bound to lipid bilayers. These arguments led eventually to the "fluid mosaic" model to be discussed below.

During the 1960's, however, other models of membrane structure were proposed to accommodate the protein and to explain results derived from biochemical and ultrastructural examination of intracellular membranes, especially mitochondria and chloroplast membranes. In thin sections, chloroplast thylakoid and mitochondrial cristae membranes often appear more as linear arrays of globular subunits than as discrete trilaminar structures. In addition, when membranes are negatively stained, globular surface structures can be seen. The most striking examples were the "elementary particles" seen on negatively stained inner mitochondrial membranes and later identified as the F1 portions of the mitochondrial ATPase. It was logically argued that since certain functional units such as the electron transport chain appeared to be quantized, they must have structural counterparts. Subunit models were widely accepted during the 1960's and many of the proposals were based on physiological evidence summarized by Korn (1969).

However, new evidence for the bilayer arrangement of lipids in membranes began to accumulate. By the late 1960's, the striking images of freeze-fractured biological membranes, showing both smooth and particulate regions , and the suggestion that one was viewing the interior of the bilayer, strongly influenced thoughts about membrane structure. The parades seen on membranc fracture faces were almost immediately-interpreted as evidence for proteins penetrating deeply into or through a lipid bilayer. However, convincing evidence accumulated only slowly, and it should

be noted that the freeze-fracture technique is not without limitations. Artifacts can be produced during freezing, fracturing, and etching. For example, plastic deformation can occur even at liquid helium temperature, and fractured surfaces can be contaminated both before and during etching. In addition, resolution is limited by the shadowing technique and is currently at best 2 to 2.5 nm. and usually not better than 4 to 8 nm.

Early arguments that the intramembrane particles (IMP's) revealed by freeze-fracturing contain protein were based on observations that particle densities were often directly correlated with protein-mediated metabolic activities or membrane protein content. Better evidence was provided later by reconstitution studies where purified membrane proteins such as bovine rod outer segment rhodopsin and later erythrocyte glycophorin were incorporated into synthetic lipid bilayers producing typical intramembrane panicles upon freeze-fracturing. Recently freeze-fracture and optical diffraction studies of purple membrane have shown that a single 11 nm IMP contains 9 to 12 bacteriorhodopsin molecules. While this provided good evidence that membrane-penetrating proteins cause the appearance of particles on fracture faces, the converse is not necessarily true. For example, it is known that large panicles can be formed in pure lipid systems devoid of membrane protein and that ice and possibly other contaminant can form particles on fracture fifes. Nevertheless in carefully prepared freeze-fractured specimens most if not all of the particles seen are causal by intramembrane proteins in association with lipid. The early freeze-fracture observations provided an apt prologue to the next membrane model: the "fluid mosaic" model of Singer and Nicolson (1972).

I. Make sentences using the words given below:

1. Proteins, been, membrane, portrayed, have, within, as, partially, monolayers, totally, or embedded, both, one.
2. Postulated, membranes, the, tension, was, low, this, to explain, arrangement, interfacial, in, found, biological.
3. Difficult, core, to transmembrane, the, becomes, if, to explains, proteins, are, peripheral, function, located, hydrophobic, all, membrane.
4. Noted, limitations, not, it, that, should, the, be, technique, is, freeze-fracture, without.
5. The, particles, proteins, on faces, membrane, penetrating, of, cause, fracture, appearance.

II. Give the antonyms to the following words.

To extend, current, to gain, initially, to cover, to allow, purified, to appear, to accept, to incorporate, salient.

III. Answer the following questions.

1. What models of membrane structure have been proposed?
2. Who was the first to account for membrane protein structurally?
3. What did their model supported by?
4. Why did Singer object to this model?
5. What models were proposed during the 1960-s?
6. Why had the bilayer arrangement of lipids in membranes appeared by the end of 1960-s?
7. Artifacts can be produced by the freeze-fractured technique only, can't they?
8. What have early freeze-fractured and optical diffraction studies shown and provided?

IV. Give the main idea of each paragraph and compare the results with your partner's.

V. Summarize the text in writing.

Part II. Singer and Nicolson's "Fluid Mosaic" Model

As originally proposed (Singer, 1971), the model was based on a bilayer with proteins inserted in a "mosaic" pattern. To account for the dynamic properties of membrane lipids and proteins and to explain the translational movements of membrane constituents, the model was then modified to the present fluid mosaic model (Singer and Nicolson, 1972). In its simplest form the model envisions freely mobile, globular amphiphilic proteins embedded in one or the other monolayer with some proteins spanning the thickness of the bilayer. Both proteins and lipids are mobile and thus in a first approximation a membrane is viewed as a two-dimensional solution of protein in lipid.

Extensive evidence for the existence of the lipid bilayer and for the mobility of lipids both translationally and transversely had already been accumulated in support of the Davson-Danielli-Robertson model. Although many membranes and specialized regions of membranes have proven to be less "fluid" and the proteins less mobile than the model would suggest, one of the earliest examples studied carefully, the disk

membranes of rod outer segments, appeared to fit the model perfectly. Such findings and the demonstration that a number of intrinsic membrane proteins have residues exposed simultaneously to both surfaces of the membrane led to a rapid acceptance of the model.

According to the fluid mosaic model, two categories of membrane proteins — integral and peripheral — may be associated with the biological membrane. As originally defined, peripheral proteins are easily dissociated from membranes by manipulating pH and ionic strength and are soluble in aqueous solvents. The model initially presented by Singer and others largely neglected such proteins and actually questioned whether or not they should be considered membrane proteins. On the other hand, integral proteins are only dissociated from membranes by reagents that disrupt hydrophobic interactions (detergents, organic solvents, chaotropic agents), and in their purified state are insoluble in neutral aqueous buffers. Exceptions to the latter statement are known, but those proteins often have undergone large structural changes or covalent modification.

If integral proteins penetrate the bilayer they should be amphiphilic. Evidence for amphiphilic character is suggested by the relatively high content of nonpolar amino acid residues in some integral membrane proteins. However, the ratio of hydrophilic to hydrophobic amino acids of most membrane proteins does not differ very much from that of soluble proteins. It must be their secondary or higher order structure rather than their primary structure that causes the amphiphilic character. Analysis of the primary structure of one of the best characterized membrane proteins, erythrocyte glycophorin, has shown that its 23 nonpolar amino acid residues are confined primarily to one region of the protein chain and thus confer hydrophobicity on that region. The polypeptide chain may be folded in an alpha-helix and is long enough to span the hydrophobic interior of the bilayer. The protein is amphiphilic because it possesses a polar, branched oligosaccharide chain covalently bound to the N-terminal end of the polypeptide, and a hydrophilic amino acid sequence at its C-terminal end. That the protein spans the membrane has been shown by chemical labeling experiments that will be discussed later.

Glycophorin is one type of protein which presumably traverses the membrane only once and contains a sufficiently long, uninterrupted sequence of hydro-phobic amino acids to do so. The other type of integral membrane protein, exemplified by the purple membrane protein bacteriorhodopsin, spans the membrane several times. Its sequence of hydrophobic amino acids is interrupted by polar and hydrophilic residues sufficient to prevent the formation of a completely hydrophobic region long enough to span the bilayer. Evidence is accumulating in favor of the hypothesis that the

arrangement of the amino acids in bacteriorhodopsin allows the formation of alpha-helical segments with hydrophilic and hydrophobic regions extending along the surface of the helix. The helical segments are thought to cluster together in the membrane with their hydrophilic faces facing each other and forming salt bridges and hydrogen bonds. The exterior of the molecule would present a hydrophobic surface to the hydrocarbon chains of surrounding lipids. Although absent from bacteriorhodopsin, a hydrophilic channel could also be formed by the intra- or intermolecular associations of similar clustered helices.

Cytochrome b5, a well-studied integral protein associated with the endoplasmic reticulum, provides another example of a functional membrane protein with amphiphilic properties. It can be extracted from the membrane either by enzymatic (lipolytic or proteolytic.) hydrolysis or by detergent treatment. The polypeptide derived by enzymatic treatment is water-soluble. The protein derived by detergent treatment, however, contains additional 44 amino acid residues that are about 60% hydrophobic. The functional component of the protein resides in its hydrophilic portion: the hydrophobic portion anchors the protein to the membrane.

I. Insert the appropriate prepositions.

1. The model was based ... a bilayer ... proteins inserted ... a mosaic pattern.
2. Extensive evidence ... the existence ... the lipid bilayer and ... the mobility ... of lipids both translationally and transversely had already been accumulated ... support ... this model.
3. ... the other hand, integral proteins are only dissociated ... membranes ... by reagents.
4. Evidence is accumulated ... favour ... this hypothesis.
5. The arrangement ... the amino acids in bacteriorhodopsin allows the formation ... alphahelical segments ... hydrophilic and hydrophobic regions extending ... the surface ... the helix.

II. Match the definitions with the words from the text.

1. to see in the mind's eye;
2. to limit, keep (something) within limits;
3. an essential part component;
4. to subject to, allow to be affected by;
5. crossing from side to side or lying across or crosswise;
6. to interrupt or cause to cease entirely;
7. to gather close together.

to cluster, constituent, to envision, transverse, to confine, to expose, to disrupt

III. Answer the following questions.

1. Why was Singer's model modified to the fluid mosaic model?
2. How is a membrane viewed initially?
3. What findings led to a raped acceptance of the model?
4. How are peripheral proteins originally defined?
5. How could they be dissociated from membranes?
6. What causes the amphiphilic character of integral proteins?
7. Prove that proteins are amphiphilic.
8. Glycophorin, as bacteriorhodopsin, traverses the membrane several times, doesn't it?
9. What does the arrangement of the amino acids in bacteriorhodopsin allow?
10. How can cytochrome b_5 be extracted from membrane?
11. What properties do the derived proteins possess?

IV. Summarize the text in writing.

V. Compare "Unit Membrane" and "Fluid Mosaic" Models. State the difference and discuss with your partner.

Text 9. **Protein Asymmetry and In-plane Arrangement**

Since polypeptide chains are inherently asymmetric, their insertion into membranes must contribute to the membrane asymmetry. Only if identical proteins or protein subunits were arranged in opposite directions across the membrane would the structure be symmetrical. No such case has been observed in biomembranes. This may in part be due to the mode of biomembrane synthesis and the electrochemical gradients which appear to exist across all natural membranes. It is also difficult to imagine a useful function in *a* typical membrane for a protein that is symmetrically distributed. Symmetric or nearly symmetric membranes, however, do often arise when model membranes are reconstituted from isolated lipid and protein components, imposing severe limitations on their use as model systems for natural membranes. It may also be noted that thus far no proteins have been shown to penetrate only half way through the membrane as postulated in the Singer-Nicolson model. However, such an arrangement is often portrayed in schematic drawings of membranes and is

used to illustrate hypotheses of membrane transport or signal transduction mechanisms.

Before reviewing the biochemical and microscopic evidence for protein asymmetry, we should note that any model of protein arrangement must account for the functional, vectorial processes of well-studied integral membrane proteins. Prime examples of functional proteins in membranes are the ion pumps which use cellular or extraneous energy sources to transport ions against concentration gradients into and out of cells; e.g., accumulating potassium and ejecting sodium. Typically, they constitute only minor components of the total membrane. For example, only 100 to 200 sodium-potassium ATPase molecules are found on one erythrocyte. Roughly one pump per square micrometer of surface. In specialized tissues such as the sarcoplasmic reticulum, however, ion pumps may account for more than 50% of the total membrane protein. In addition to the sodium-potassium pump, calcium and proton pumps (F1F0 ATPase and bR) have been isolated and characterized.

Most of the pumps are electrogenic; i.e.. they generate a membrane potential which in turn can be used to drive other transport processes via specific channels or exchange proteins. Passive sodium and potassium fluxes across the axon membrane, for example, are thought to occur through specific gated channels formed by polypeptides and the opening and closing of the channels to be controlled by the membrane potential. The number of these channels has been estimated at 10 to 100 per square micrometer of axon membrane. The function of these proteins seems to indicate that they span the membrane. In general, however, proteins with known functions account only for a small fraction of the proteins found in most membranes. For the vast majority of membrane proteins no such clues exist for their arrangement in the membrane.

Not too much is known about the in-plane arrangement of proteins, and membrane protein function so far has provided few clues. There are, however, a few well-studied cases of lateral segregation of membrane proteins. At sites of cell-to-cell contact in multicellular organisms, membrane-to-membrane contacts, "junctions," can be seen, which are characterized by specific aggregations of membrane proteins. Of these, "gap junctions" often show a hexagonal in-plane lattice occupying up to one square micrometer of cell surface. They provide low resistance diffusion pathways, and couple cells electrically. Another striking example of lateral protein segregation and functional in-plane differentiation is found in the plasma membrane of *Halobacterium halobium.* When cells are kept at low oxygen tension in the light, a portion of the plasma membrane differentiates to contain many copies of a single protein, bacteriorhodopsin, packed into a highly ordered hexagonal array.

Bacteriorhodopsin acts as a light energy transducer, generating an electrochemical gradient by vectorial translocation of hydrogen ions when it absorbs visible light.

I. Find the synonyms to the following words and word-combinations in the text.

By means of, constituent, to compute, infusion, boundary, to originate from, remarkable, to assimilate, congenitally, similar, breach, rigid.

II. Make sentences using the words given below.

1. Asymmetry, the, polypeptide, membranes, the, to insertion, membrane, chains, contribute, into, of.
2. Constitute, which, energy, only, of, membrane, ion, use, the extraneous, to, total, the, minor, cellular, transport, components, sources, pumps, ions, or.
3. Other, by, channels, a, potential, of, exchange, can, transport, membrane, be, means, or, drive, processes, proteins, to used, particular.
4. Electrically, junctions, low, and, diffusion, gap, cells, provide, pathways, resistance, couple.

III. Answer the following questions.

1. Proteins are always symmetrically distributed in natural membranes, aren't they?
2. When may symmetric or nearly symmetric membranes take place?
3. Where is such an arrangement of proteins used?
4. What types of pumps have been isolated and characterized?
5. Prove that most of the pumps are electrogenetic.
6. What examples of lateral protein segregation are found in biomembranes?

IV. Summarize the text in writing.

Text 10. Biochemical and Electron-microscopic Evidences

Membrane proteins and polypeptides may be solubilized with detergents such as Triton, octyl glucoside, or sodium dodecyl sulfate (SDS), and separated by electrophoresis in polyacrylamide gels (PAGE) or by column chromatography. The SDS-PAGE method provided the first generally useful means for separating and characterizing integral biomembrane proteins. However, because oligosaccharide-containing polypeptides, and other membrane polypeptides, travel anomalously in

SDS gels, molecular weight assignments cannot be made unequivocally. Gel chromatography gives only the radius of gyration of the detergent-protein micelle, and accurate molecular weight assignments require additional measurements. Nevertheless, many membrane proteins can now be isolated in pure form, a number of complete amino acid sequences have been determined, and the first three dimensional crystals of intrinsic membrane proteins have recently been obtained.

Two types of experiments employing membrane-labeling followed by detergent solubilization and electrophoresis have set the pattern for experimental analysis of protein arrangement in membranes. The first approach is to label intact cells with nonpenetrating chemical reagents or enzymes, then to perturb the membrane to expose its interior surface, and finally to compare the patterns of labeling by SDS-PAGE and or polypeptide fingerprinting. In studies of the RBC membrane, for example, intact cells are compared to lysed cell "ghost" membranes or to "inside-out" vesicles whose original cytoplasmic side is exposed to the exterior and extracellular side to the interior.

A variety of chemical reagents have been used for membrane labeling, most with the often poorly documented assumption that they cannot penetrate through the membrane. In addition to permeability uncertainties, cell lysis may produce alterations in membrane structure or permeant labels may react during permeation. Thus, the additional reactivity may not indicate exposure of sites on the cytoplasmic surface, but rather may indicate sites on the interior of the membrane or newly generated sites on the outside. Attempts to circumvent this problem have been made using combinations of nonpenetrating and penetrating reagents to sequentially label intact cells, or labels such as photoaffinity probes have been used which are activated only after penetration.

A second method uses enzymatic labeling to identify exposed polypeptide by clipping off a portion or to "tag" it by covalent addition of an optical or radioisotopic label. Cleavage of exposed polypeptides has been performed with trypsin, pepsin, papain and a variety of mixed proteolytic preparations (pronases). Glycolytic enzymes have been used to identify glycoproteins. Neuraminidase, for example, an enzyme capable of releasing N-acetyl neuraminic acid (sialic acid) has been extensively used in studies of the erythrocyte. Beta-galactosidase has also been used to remove terminal galactose residues. One of the more widely used approaches is that of lactoperoxidase iodination of the tyrosine (and possibly histidine) residues of polypeptides in the presence of hydrogen peroxide. Oligosaccharide residues have also been labeled by enzymatic oxidation coupled with tritiated borohydride reduction. Glutamine transaminase has been used to exchange labeled amines for the

accessible amide residues of glutamine in membrane polypeptides. In general, enzymatic methods are preferable to strictly chemical procedures because membrane penetration is less of a problem and reaction conditions may be kept closer to physiological.

Because the erythrocyte membrane is a convenient system and has been well studied, most of the approaches to labeling and analyzing membrane proteins have included an examination of the red blood cell (RBC). Despite widely divergent labeling methods, the consensus of data indicates that treatment of intact RBC's labels only two major polypeptide fractions (PAGE bands): band 3 (component a) and PAS 1 (glycophorin). Other labeling experiments also suggest that polypeptides in these two classes span the thickness of the membrane. The remainder of the polypeptide bands (seven or more depending on the technique) are labeled only when "leaky" ghosts are treated, suggesting that most of their polypeptide chains and reactive sites are accessible only on the cytoplasmic side.

Although many other plasma membranes have been examined for polypeptide and lipid asymmetry, few experiments have met rigorous criteria of purity, sided-ness. and analysis (Rothman and Lenard. I977). Nevertheless, wherever such criteria have been met best, such as in certain virus and bacterial membrane systems, the general principle of asymmetry has been confirmed.

Electron microscopy has also been used to examine the distribution of reactive sites on one or the other side of the membrane. Although cytochemical approaches involving formation of electron-scattering precipitates at the site of reactivity are always subject to the artifacts caused by diffusion or rearrangement during subsequent processing, the asymmetry of enzymatic activity, especially that of the sodium-potassium ATPase, has been well documented. Labeling with large markers such as the iron-containing protein ferritin is less subject to diffusion repositioning, but accessibility is a problem. The large markers cannot penetrate intact, unmodified membranes, and their large size can mask sites that might otherwise be reactive. Ferritin conjugates have been constructed using antibodies for antigen localization, lectins for oligosaccharide mapping, and cationic derivatives for detecting sites of high electronegativity. Ferritin. hemocyanin, virus particles, and synthetic polymer beads have provided particularly useful markers for freeze-etching and scanning electron microscopy. The topographic distribution of the large molecules can be easily assessed. When ferritin is used with freeze-etching, it is also possible to correlate surface patterns with fracture-face particle patterns and thus provide cytochemical information about the particles.

I. Find the antonyms to the following words in the text.

To attach, to calm, to help, to exclude, detrimental, ambiguously, external, troublesome, mild, identical, preceding.

II. Define whether the following statements are true or false and correct the false statements.

1. Molecular weight assignment can be made easily with the SAS-PAGE method.
2. Intact cells can be labeled both with nonpenetrating chemical reagents and enzymes.
3. Glycoproteins have been used to identity glycolic enzymes.
4. Few membrane proteins can be isolated in pure form.
5. The additional reactivity should always indicate exposure of site on the cytoplasmie surface.
6. Most of the approaches to labeling and analyzing membrane proteins have involved an examination of the red blood cell.
7. Labeling with large markers is more subject to diffusion repositioning.

III. Answer the following questions.

1. In what way may proteins and polypeptides be solubilized and separated?
2. What did SDS-PAGE method provide?
3. Does this method have any drawbacks?
4. What scheme for experiments analysis of protein arrangement is used?
5. What does cell lysis produce in addition to permeability uncertainties?
6. What does a second method use enzymatic labeling for?
7. Give some examples of enzymes used in studies of exposed polypeptides.
8. What docs the treatment of intact RBC's label?
9. What do other labeling experiments propose?
10. What have the biochemical experiments confirmed?
11. What is the main problem in labeling with large markers?
12. What do ferritin and other proteins provide?

IV. Write a short summary on the text.

Text 11. Protein Mobility. Rotational and Translational Movement

Several categories of protein mobility may be distinguished : rotation, around an axis normal to the plane of the membrane: translation or lateral diffusion, in the plane of the membrane or across it; and vibration, in several forms. Vibrational and conformational changes of membrane proteins will not be considered here because little experimental data are available. On the other hand, for many membrane proteins, strong evidence supports the existence of rotational and lateral diffusion. Translation across the membrane apparently involves complex mechanisms which are not yet understood.

The earliest experiments which gave convincing evidence for the in-plane mobility of proteins made use of the special properties of rhodopsin in the disk membranes of vertebrate visual cells. Rhodopsin is an intrinsic membrane protein, constituting approximately 90% of the total disk protein. It has a strong absorbance band in the visible region, and that band can be bleached by light. Blasie and Worthington used X-ray scattering from rod outer segments to show that the rhodopsin molecules behaved as independent 4 to 5 nm particles in a two-dimensional liquid. Richard Cone subsequently used the transient dichroism induced by a flash of polarized light to show that rotational diffusion occurred about an axis perpendicular to the membrane plane with a relaxation time of about 20 μs at 20 0C. Similar techniques have been used with many other membranes. If no endogenous chromophores are present in the protein, exogenous chromophores can be covalently bound to it; fluorescent chromophores are often used as probes.

Rapid lateral diffusion has also been shown for rhodopsin in the photoreceptor membrane by Poo and Cone (1974) using microspectrophotometric methods. They isolated rod outer segments and bleached one side of the cylindrical rod. Because disk membranes are stacked normal to the long axis of the rod, one "half" of each disk remained unbleached. Microspectrophotometry of each half of the rod following bleaching revealed a rapid increase in absorbance in the bleached portion and decrease in absorbance in the unbleached portion. Control experiments showed that rapid lateral diffusion of rhodopsin in the plane of the membrane was the only valid conclusion.

Rapid translational movements were elegantly demonstrated in the experiments of Frye and Edidin (1970). They fused cells derived from mouse and human tissue culture lines with *Sendai* virus and labeled the mouse and human surface antigens with different fluorescent antibodies. Redistribution of surface components was monitored by fluorescence light microscopy. At 37 °C heterokaryons showed two

distinct staining regions after 5 min, and within 40 min totally intermixed dyes. After determining the temperature dependence of mixing and conducting a number of control experiments, the authors concluded that the antigens were highly mobile in the plane of the membrane, with diffusion coefficients comparable to those of lipids. These experiments set the pattern for the numerous subsequent determinations of protein mobility in the plane of the membrane at the light microscope level (Edidin, 1974).

Electron microscopy has also shown redistribution of membrane proteins either by monitoring protein-bound surface labels such as ferritin or by examination of freeze-fracture images of cells under different physiological conditions. One early and compelling example was the demonstration of reversible, pH-dependent particle clustering in freeze-fractured erythrocyte ghost membranes, and the correlation of surface ferritin-labeling patterns with the particle patterns on the fracture face. This clustering, however, is dependent on the removal of peripheral membrane protein and is not seen in intact erythrocytes.

We emphasize that not all proteins can freely diffuse in membranes under physiological conditions. Both partially and totally restricted transnational mobility of membrane proteins has been documented for many membranes, especially the plasma membrane. Regional bleaching of fluorescent-labeled fibroplast membrane proteins has shown a slower diffusion (2.6 x 10-10 cm2 s-1)than that of lipid labels in the same membrane and total immobilization of part of die proteins. The first report of extreme immobility came from fluorescence microscopy of erythrocyte ghost membranes labeled with fluorescein isothiocyanate. One half of a single, flattened ghost was bleached and the redistribution of residual fluorescence monitored photometrically. Essentially no redistribution of label was observed over a period of 20 min at 20o to 23 oC, and an upper limit on the diffusion coefficient was placed at 3 x 10-12 cm2 s-1. This contrasts sharply with the apparently unrestricted lateral diffusion of rhodopsin in the disk membranes. The intermediate case of partial restriction seen in the fibroblast membrane is probably the more general one and poses interesting questions about the physiological role and control of lateral diffusion in membranes.

I. a) Match the following words with their definitions. Use English-English dictionaries if it's necessary.

Rotation, translation, vibration, mobility, diffusion, redistribution, total, band, bleached, to scatter, to monitor, to fracture.

b) Make up your own sentences using these words.

II. Answer the following questions.

1. What categories of protein mobility may be distinguished?
2. What properties does rodopsin have?
3. What did the experiments of Blasic and Richard Cone show?
4. When can exogenous chromophones be coralently bound to the protein?
5. What methods were used to show rapid lateral diffusion of rodopsin?
6. What did this methods reveal?
7. What experiments were concluded by Fryle and Edden?
8. Why were their experiments so important in the 1970-s?
9. What have experiments with microscopy also demonstrated?
10. PH-dependent particle clustering can be easily seen in intact erythrocytes, can't they?
11. Can all properties freely diffuse in membranes under physiological conditions?
12. What has regional bleaching of fluorescent labeled fibroplast membrane proteins revealed?
13. The results of this experiment don't contrast with the apparently unrestricted lateral diffusion of rodopsin, do they?

IV. Write a brief summary on the text.

Text 12. **Regulation of Protein Mobility**

Three types of control of membrane protein mobility should be considered: lipid dominated, integral protein dominated, and peripheral protein dominated.

The distribution of membrane proteins can be influenced indirectly by factors that regulate lipid arrangement. As discussed in Sect. 1.2.3, the mobility of individual classes of membrane lipids shows temperature-dependent transitions. Thus, as the temperature is lowered, phase separations of mixed lipids can occur and produce regions within the bilayer that are less fluid and regions that are more fluid. If incorporated into such mixtures, integral membrane polypeptides will typically partition to the more fluid phase and be restricted in their movements to such regions. This has been demonstrated in model systems; for example, glycophorin was reconstituted with the synthetic phospholipids dimyristoyl phosphatidylcholine (DMPC) and dipalmitoyl phosphatidylcholine (DPPC). Below the phase transition temperature of DPPC, but above that of DMPC, freeze-fracture revealed smooth patches (thought to represent the least fluid portions of the membrane) surrounded by

particles in distinct reticular or patchy arrays. It is unknown if such exclusions regularly occur in native membranes, especially in those whose phase-separation temperatures are extremely low or extremely broad due to the presence of cholesterol. However, freeze-fracture electron micrographs of native membranes of prokaryotes, such as *Escherichia coli* that lack cholesterol or of *Acholeplasma laidlawii* depleted of cholesterol and enriched with lipids susceptible to temperature manipulation, show exclusion of IMP's from certain regions of the membrane indicating sites of phase-separated lipids. Numerous studies, mainly of prokaryotes, indicate that the cells grow best at temperatures just above or actually within the transition range. Concentration of protein in the more fluid regions of the membrane has obvious implications for reaction rates of metabolic processes.

Control of membrane protein mobility may also be dominated by the integral proteins. For example, several polypeptides may associate farming single macromolecular units. Again drawing an example from the erythrocyte membrane, chemical cross-linking studies coupled with SDS-PAGE have shown close association of intramembrane aggregates. The diameters of freeze-fracture particles suggest that they represent such aggregates. Moreover, surface-labeling experiments show consistent association of different ferritin conjugates with the particle aggregates, suggesting that single particles may contain multiple receptors. Since such aggregation may occur during freezing or chemical cross-linking, the data are not entirely conclusive. A better example is the spontaneous aggregation of bacteriorhodopsin molecules to form a crystalline lattice in the fluid cell membrane of halobacteria. Other good examples are found in the aggregation of connexin molecules to form gap junctions in animal tissues. There is increasing evidence that aggregation of receptor proteins in the plane of the membrane, after ligand binding, is an essential step in signal transduction.

Finally, and perhaps most importantly, regulation of mobility may occur through interactions between membrane proteins and proteins located on the membrane surface or in the cytoplasm adjacent to the inner membrane surface. Examples of cytoplasmic control of mobility of membrane components are found in directed movements of regions of the membrane: e.g., during amoeboid locomotion, phagocytosis or pinocytosis, secretion, or movement of receptors during "cap" formation in lymphocytes. In all these cases electron microscopy has shown underlying cytoskeletal elements, particularly microtubules or filamentous biopolymers with actin-like properties. In addition, drugs such as cytochalasin B and colchicine which inhibit or break down cytoskeletal elements interfere with these processes. Moreover, in some instances it has been shown that cytoskeletal elements

bind strongly to the surface of the membrane either directly or via specialized intermediary molecules. Recently much attention has been focused on the RBC cytoskeletal elements, the spectrin complex. Apparently, paired dimers of spectrin. an elongated molecule, are attached to the cytoplasmic side of the membrane by other molecules which in turn interact with the anion channel, band 3. The patterns of fibronectin, an outer-membrane surface protein, also appear to be determined by underlying membrane proteins and their interaction with cytoskeletal elements.

I. Fill in the gaps with the appropriate preposition.

1. Phase separations ... mixed lipids can occur and produce regions ... the bilayer.
2. Freeze-fracture electron micrographs ... native membranes ... prokaryotes show-exclusion ... IMP's ... certain regions ... the membrane.
3. The cells grow best ... temperature ... or actually ... the transition range.
4. Regulation of mobility occur ... interactions ... membrane proteins and proteins located ... the membrane surface.
5. Paired dimmers of spectrin are attached ... the cytoplasmic side ... the membrane ... other molecules.
6. Some prokaryotes were enriched ... lipids susceptible ... temperature manipulation.

II. Answer the following questions to the text and discuss your answers in groups.

1. What types of control of membrane protein mobility should be considered?
2. When can phase separations of mixed lipids occur?
3. What affect the distribution of membrane proteins?
4. What has been demonstrated in model systems? Give examples.
5. Do the shown exclusions regularly occur in native membrane?
6. Under what condition do the cells grow best?
7. Control of membrane protein mobility is dominated by the integral proteins, isn't it? Give some examples.
8. Where may regulation of membrane protein mobility finally occur?
9. Where are examples of cytoplasmic control of mobility of membrane components found?
10. What have all experiments with electron microscopy shown?
11. How are cytoskeletal elements attached to the surface? Illustrate it with some examples.

III. Summarize the text in writing. Discuss your results in groups.

Text 13. Carbohydrate Arrangement in Biomembranes.Oligosaccharide Labeling and Localization

Carbohydrates are found in small amounts covalently bound to proteins and lipids in most plasma and intracytoplasmic membranes. Although carbohydrate is usually less than 10 % of the total membrane mass, the mass in a single glycoprotein molecule may range to 50% or more. In glycophorin, for example, 60% of the total mass of the molecule consists of moderately branched carbohydrate chains attached near the N-terminal end of the polypeptide. These extracellular surface carbohydrates of the erythrocyte membrane determine its blood group specificity. Membrane oligosaccharides are often implicated in numerous other important functions such as cell-to-cell interaction and communication, binding of small molecules, antigen-antibody recognition, and enzyme recognition. Unfortunately, their structural features in situ are only beginning to be studied and they have been generally overlooked in most models. Other polymeric carbohydrates found in large amounts on the surfaces of many cells constitute the cell walls of prokaryotic and plant cells and the glycocalyx of animal cells. Such structures are not considered membrane components and will not be discussed here.

The distribution of membrane carbohydrates has been studied by a variety of chemical, immunological, and enzymatic approaches. For example, carbohydrates can be oxidized to obtain free aldehyde groups which in turn will produce Schiff bases with amino groups of different labels such as dyes for light microscopic investigations or ferritin and other markers for electron microscopy. Positively charged probes such as polycationic ferritin or colloidal iron hydroxide can be used to label neuraminic acid (sialic acid) residues. Sialic acid is a negatively charged amino sugar frequently found on extracellular surfaces of eurokaryotic plasma membranes. Antibodies specific for blood group determinants known to be oligosaccharides will bind selectively to extracellular surfaces of membranes. Lectins, proteins isolated mainly from plants, bind with various specificities to certain sugars such as glucose, glucosamine. galactose, mannose, etc. Coupled to fluorescent dyes or ferritin, lectins are widely used to label cell surface components. Enzymatic modification has been used to label membrane surfaces. Enzymatic cleavage allows one to increase the precision of carbohydrate localization when the label alone shows insufficient specificity. For example, if pretreatment with neuraminidase abolishes colloidal iron hydroxide labeling, then binding is generally assumed to be due to a sialoglycoprotein.

Such cytochemical techniques have established that the carbohydrates are

generally found on the extracellular surfaces of plasma membranes or the noncytoplasmic surfaces of intracellular membranes. Such orientation is thought to help anchor the membrane molecule in its orientation across the plane of the bilayer. However, practically nothing is known about the conformation of the carbohydrate chains on the membrane surface. Although membrane models sometimes show them extending out from the surface at right angles, there is little experimental evidence for this.

I. Answer the following questions.

1. Where are carbohydrates found?
2. What determines blood group specificity of glycophorin?
3. Where are membrane oligosaccharides often involved?
4. Structural features of membrane oligosaccharides have been studied thoroughly, haven't they?
5. What methods have been utilized to study the distribution of membrane carbohydrates?
6. What can be positively charged probes be used for?
7. What substances are used to label cell surface components and membrane surfaces?
8. What does enzymatic cleavage allow?
9. What have cytochemical techniques showed?
10. Do we have enough experimental evidence to prove the conformation of the carbohydrate chains on the membrane surface?
11.

II.Find the synonyms to the following words in the text.

Peculiarity, to extract, to employ, to destroy, identification, to tie (2), splitting, accuracy, scanty, alteration.

Revision task

I. Trace the development of biomembrane models (pp. 4 – 36).
Write a summary.
II. Compare your own summary with the one on p. 96
III. Discuss the points with your partner.

Text 14. Membrane Potentials

In living cells an electrical potential difference exists between the cytoplasm and the extracellular medium, with the inside of the cell being negative with respect to the outside. The potential is called resting potential It may vary considerably between different types of cells, but it is always smaller than 100 mV. The resting potential is caused by the unequal distribution of ions in the inside and outside solutions on both sides of she plasma membrane surrounding the cell. Therefore, the resting potential is also called membrane potential.

Measurement of Membrane Potentials

Giant axons of the squid are so thick (internal diameter up to 1 mm) that an electrode can be introduced axially into its axoplasm. The membrane potential then can be directly recorded as the potential difference between the inner electrode and an electrode in the extracellular solution. A similar procedure may be applied to thin nerve and muscle fibers, into an internal axial electrode cannot be inserted. One then electrically isolates two sections of the fiber by overflowing sucrose or by an air gap and cuts the fiber on one side in a solution producing no liquid junction potential with the cytoplasm. The potential difference between the two extracellular fluid pools is then equal to the membrane potential.

In general, cells are so small that the two methods described above are not applicable. To measure the membrane potential in these unfavorable cases the plasma membrane has to be penetrated by thin microelectrodes (tip diameter 0.1 to 0.5 um) to record the membrane potential with respect to an electrode in the extracellular solution. However, membrane potentials measured in this way may be seriously disturbed by potentials arising at the microelectrode tip or by leaks around the penetrating electrode.

An alternative method of determining membrane potentials is to measure the equilibrium distribution of an ion between the extra-and intracellular phases from which the membrane potential can be calculated. For example, the concentration of charged dyes in the cytoplasm can be obtained from fluorescence or absorption measurements. This optical method has been applied to a great variety of cells in recent years and has yielded membrane potentials comparable with the results from electrical measurements. However, the optical method is only applicable if the dye is equally distributed in the cytoplasm, if it does not form di- or polymers and if it does not bind to cell organelles and is not accumulated by such constituents.

I. Match the words given below with their definitions:

a) put, fit, place (smth. in, into, between, etc.)
b) separate, keep apart from the others
c) make practical use of (research, discovery)
d) make a way into
e) break the quiet, calm, peace or order of, put out of the right or usual position, upset
f) find the size, extent, volume, degree, etc.
g) give a result or profit
h) make or become greater in number or quantity, come or gather together, heap up.

to measure, to accumulate, to yield, to insert, to penetrate, to disturb, to apply, to isolate

II. Skim the text, answer the following questions, then compare your answers with your partners.

1. How can the membrane potential be recorded?
2. In what way are two sections of the fiber isolated?
3. What is necessary to measure the membrane potential in cells?
4. What can membrane potential be disturbed by?
5. What is an alternative method of determining membrane potentials?
6. What has the application of the optical method yielded in recent years?

II. Give the main idea of each paragraph.

IV. Render the context of this text.

Text 15. **Origins of Membrane Potential**

As already described, the membrane potential is caused by the unequal distribution of ions in the extra- and intracellular solutions. **Table 1.** gives measured ion concentrations for a carefully studied preparation, the frog skeletal muscle.

Typical for this and for other investigated cells is a much higher intracellular K^+ concentration than in the bathing medium. On the other hand, the extracellular solution contains more Na^+ and Cl^- ions than the cytoplasm. **Table 1.** also reveals an approximate balance of positive and negative charges for Na^+, K^+, and Cl^- ions in

the outside solution, whereas the charges of Na^+, K^+ ions in the cell interior are **not** neutralized by the small amount of Cl^- ions. The balance is then accomplished **by** organic anions which are partially fixed in cytoplasmatic proteins.

Table 1. Ion concentrations and equilibrium potentials in frog muscle. Values **for** outside and inside concentrations. Equilibrium potentials are calculated **from** Equation (7) with $RT/F=25$ mV

	c_0 (mM)	c_i (mM)	E (mV)
Na^+	120	9.2	+67
K^+	2.5	140	-102
Cl^-	120	4	-86

According to these ion distributions in the extra- and intracellular spaces, **the** resting potential across the plasma membrane could have the following origins:

a) Fixed anions in the cytoplasm could create a negative Donnan potential **with** respect to the outside solution, similar to the potential produced by polyelectrolytes **in** an ion exchanger.

b) The plasma membrane could have different permeabilities for Na^+, K^+, and Cl^- ions. According to this ion selectivity a diffusion potential would develop across **the** membrane.

c) To maintain the concentration differences between the outside and **inside** compartments, an active ion transport could take place in the plasma membrane which by itself could contribute to the membrane potential.

In the following sections these three possible origins of the membrane potential will be discussed in detail.

I. Change the false statements so that they are true.

1. The membrane potential is caused by the equal distribution of ions in the extra- and intracellular solutions.
2. The extracellular solution contains less Na^+ and Cl^- ions than the cytoplasm.
3. The charges of Na^+, K^+ ions in the cell interior are neutralized by the **small** amount of Cl^- ions.
4. The balance is accomplished by organic anions which are completely fixed **in** cytoplasmtic proteins.

III. *Give the main idea of this chapter.*

III. Answer the following questions in pairs.

1. What does the unequal distribution of ions in the extra- and intracellular solutions cause?
2. What does *Table 1.* reveal?

IV. Find these words in the text and give their definition.

a) intracellular
b) approximate
c) outside
d) investigated
e) bathing

Text 16. **Donnan Potential**

Figure 5. is a schematic representation of a phase with negative fixed charges in contact with an electrolyte solution of univalent ions. With X we denote the concentration of negative fixed charges and with c the ion concentration in the bulk of the electrolyte solution. We assume that ions from the electrolyte solution may diffuse into the phase of fixed charges. Due to the presence of negative fixed charges the concentration c_+ of mobile cations in this region will be higher than the concentration c_- of mobile anions from the electrolyte solution. The negative fixed charges also will create a potential drop $\Delta\varphi$ between the electrolyte solution and the region of fixed charges. This so-called Donnan potential may be calculated in the following way:

In equilibrium the concentrations of mobile cations and anions are connected by the Boltzmann equations

$$c_+ = c\,exp\left(-\frac{F\Delta\varphi}{RT}\right) \qquad (1)$$

$$c_- = c\,exp\left(+\frac{F\Delta\varphi}{RT}\right) \qquad (2)$$

(F: Faraday constant, R: gas constant, T: absolute temperature, $RT/F=25$ mV at 17°C).

Thus

$$c_+ \cdot c_- = c^2 \qquad (3)$$

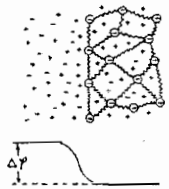


Fig. 5. Ion distribution and potential profile between an electrolyte solution and a phase of fixed charges. +, — : mobile cations, anions: Θ; negative fixed charges; $\Delta\varphi$: Donnan potential

In addition to the Donnan equation (3) the balance of charges

$$c_+ = c_- + X \qquad (4)$$

in the phase of fixed charges must be fulfilled. Solving the equations for the Donnan potential $\Delta\varphi$ yields:

$$\Delta\varphi = -\frac{RT}{F} ln \frac{c_+}{c} \qquad (5)$$

with

$$c_+ = \frac{X}{2}\left\{1+\sqrt{1+\left(\frac{2c}{X}\right)^2}\right\} \qquad (6)$$

To estimate the magnitude of the Donnan potential in frog muscle we first consider the extreme case that except Cl^- only negative fixed charges are present in the interior of the muscle fiber. From Table 12.4 we then obtain X= 145 mM, and with an extracellular ion concentration of c= 120 mM the Donnan potential becomes $\Delta\varphi$ = - 14 mV. If the intracellular anions are only partially fixed, the amount of the Donnan potential decreases accordingly. In contrast to the calculated values, the measured resting potential in frog muscle is approximately -90 mV. Hence a Donnan potential between the outside solution and the cytoplasm can only yield a small contribution to the membrane potential, the essential portion must be created by the plasma membrane.

I. Mark the statements **T.** *if they are true or* **F.** *if they are false.*

f) With X we denote the ion concentration in the bulk of the electrolyte solution.
g) We assume that ions from the electrolyte solution may diffuse into the phase of fixed charges.
h) This so-called Donnan potential cannot be calculated in anyway.
i) The measured resting potential in frog muscle is exactly – 90 mV.
j) A Donnan potential between the outside solution and cytoplasm can only yield a small contribution to the membrane potential.

II. Give synonyms to the following words.

to denote, to assume, to create, to calculate, to connect, to estimate, to consider.

III. Answer the following questions.

1. What does *Fig. 1.* illustrate?
2. What do the symbols in the equation denote?
3. How can Donnan potential be calculated?
4. What shall we first consider to estimate the magnitude of the Donnan potential in frog muscle?
5. When does the Donnan potential decrease?

IV. Give a written summary of the text.

Text 17. Diffusion Potentials at Membranes. Nernst Equation

We consider a membrane separating two electrolyte solutions of unequal composition and start with the simple case of only one membrane-permeable ion species, e.g., K^+. The K^+ ions tend to diffuse along their concentration gradient from the solution of high K^+ concentration through the membrane into the solution of low K^+ concentration. However, they cannot reach the bulk of the low concentration solution since they are held back by impermeable anions left behind at the opposite membrane side. Thus two thin layers of excess positive and negative charges are created at either of the membrane surfaces. This electrostatic double layer generates a potential difference similar to the voltage between the plates of a charged condenser. The potential is called diffusion potential since it originates from the diffusion of membrane-permeable ions.

In the case of only one membrane-permeable ion species an equilibrium state is established in which the ion diffusion across the membrane is abolished by the created diffusion potential. The diffusion potential is an equilibrium potential and given by the Nernst equation

$$E = \frac{RT}{zF} ln \frac{c_0}{c_i} \qquad (7)$$

where z is the valence of the permeant ion ($z<0$ for anions), and c_0, c_i are the bulk concentrations of this ion in the outside and inside solutions. **Table 1.** contains values of equilibrium potentials for Na^+, K^+, and Cl^- ions calculated from **Eq. 7.** It is obvious that diffusion potentials can reach values up to 100 mV and thus may give a considerable contribution to the resting potential.

I. Complete each sentence with a word or phrase given below.

1. The K^+ ions tend to diffuse along their ... .
2. They cannot reach the bulk of the low concentration solution since they are held back by ... .
3. Thus two thin layers of ... positive and negative charges are created.
4. This electrostatic ... generates a potential difference similar to the ... between the plates of a charged condenser.
5. The potential is called ... since it originates from the diffusion of membrane-permeable ions.
6. It is ... that the diffusion potentials can reach ... up to 100 mV.

excess, double layer, diffusion potential, concentration gradient, values impermeable anions, voltage, obvious

II. Answer the following questions.

1. What case has been considered in this chapter?
2. How do the K^+ ions tend to defuse?
3. Why can't they reach the bulk of the low concentration solution?
4. Where are two thin layers of excess positive and negative charges created?
5. Why is the potential called diffusion potential?
6. What equation can the diffusion potential be illustrated by?

III. Give antonyms to the following words.

to separate, to diffuse, behind, thin, similar, to abolish, obvious.

IV. Give the main idea of this chapter. Discuss with a partner your choice for topic sentence.

Text 18. Diffusion Potentials at Membranes. Goldman Equation

In reality, biological membranes are always permeable to several ion species. If cations and anions can cross the membrane, the diffusion potential is no longer stationary, because the migration of positive and negative charges through the membrane removes excess charges on the membrane surfaces. Thus the concentration differences across the membrane and the diffusion potential slowly decay and finally vanish. In living cells the equalization between the extra- and intracellular spaces is

prevented by active ion transport processes. Therefore, we will assume in the following that the ion concentrations in the outside and inside solutions remain constant even if the plasma membrane is permeable to several ions. The diffusion potential is then stationary ,and may be calculated from the condition of vanishing electrical current in the resting state. Since Na^+, K^+ and Cl^- are the main mobile ions in the extra- and intracellular solutions, this condition reads

$$J_{Na} + J_K - J_{CL} = 0 \qquad (8)$$

J_n is the net flux of ion species n which is composed of two parts: Ions move by diffusion along their concentration gradient dc/dx, and in addition they experience a driving force in an electrical potential gradient $d\varphi/dx$. If the coupling between different fluxes is neglected, the flux J thus may be described by the Nernst-Planck equation (D: diffusion coefficient)

$$J = -D\left\{\frac{dc}{dx} + zc\frac{F}{RT}\frac{d\varphi}{dx}\right\} \qquad (9)$$

If only one ion species is permeable, the condition $J=0$ yields the relation

$$\frac{d\ln c}{dx} + \frac{zF}{RT}\frac{d\varphi}{dx} = 0 \qquad (10)$$

which upon integration over the coordinate x leads back to the Nernst equation (7). If instead the general condition **(8)** has to be fulfilled, the integration requires additional assumptions. A straightforward integration can be performed if the membrane is considered as a homogeneous phase and if it is assumed that the drop of the electrical potential between the outside and inside solutions takes place only across the membrane and occurs with a uniform gradient. This implies a constant electric field strength in the membrane phase and the relation $d\varphi/dx=E/d$, where E is the diffusion potential across the membrane of thickness d. Introducing this "constant field approximation" into the Nernst-Planck equation **(9)** and integrating yields:

$$J = P\beta\frac{c_i e^{\beta} - c_0}{e^{\beta} - 1} \qquad (11)$$

where $P=D/d$ is the membrane permeability coefficient and β denotes the expression zFE/RT.

Inserting the flux equations (11) for Na^+, K^+ and Cl^- ions into the condition **(8)** and solving for the diffusion potential E gives the so-called Goldman equation

$$E = \frac{RT}{F}\ln\frac{P_{Na}[Na]_0 + P_K[K]_0 + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_0} \qquad (12)$$

where the brackets [ ] denote the outside (o) and inside (i) concentrations of the respective ions. The Goldman equation can also be derived if instead of the constant

field approximation less severe assumptions on the profile of the electrical potential in the membrane phase are applied. If the membrane is permeable to only one ion species, the Goldman equation reduces to the Nernst equation of the respective ion. In general, the diffusion potential E lies between the equilibrium potentials of the permeant ions where the contributions of the individual ions are weighted in proportion to their relative permeabilities.

I. Put each verb in the correct space.

decay, prevent, assume, occur, lie, vanish, experience, take place, denote

1. The concentration differences across the membrane and the diffusion potential slowly ... and ... finally ... .
2. Therefore, we ... that the ion concentrations remain constant.
3. Active ion transport processes ... the equalization between extra- and intracellular spaces.
4. In addition ions ... a driving force in an electrical potential gradient d_{cp} / d_x.
5. The drop of the electrical potential between the outside and inside solutions ... ... only across the membrane and ... with a uniform gradient.
6. The brackets ... the outside and inside concentrations of the respective ions.
7. In general, the diffusion potential E ... between the equilibrium potential of the permeant ions.

II. Find words in the text corresponding to the following definitions.

a) group having some common characteristics able to breed with each other but not with other groups.
b) act of joining, link, etc. that joins two parts.
c) statement of equality between two expressions.
d) connection; what there is between one thing, person, idea, etc. and another or others.
e) almost correct amount or estimate

approximation, species, equation, coupling, relation

III. Answer the following questions.

1. Why do the concentration differences across the membrane and the diffusion potential decay and vanish?
2. What is the equalization between the extra- and intracellular spaces prevented by?

3. We assume that the ion concentrations in the outside and inside solutions remain constant, don't we?
4. Describe the general condition **(8)**.
5. When does the integration require additional assumptions?
6. When can a straightforward integration be performed?
7. What does the Goldman equation demonstrate?

IV. Write a brief summary of the text.

Text 19. Ion Permeabilities in the Resting State

According to the unequal distributions of Na^+, K^+, and Cl^- ions between the extra- and intracelluiar spaces, the equilibrium potential is positive for Na^+ ions, but negative for K^+ and Cl^- ions (**Table 1.**). Hence a negative diffusion potential close to the resting potential is obtained from the Goldman equation (12.49) only if the Na permeability P_{Na} is small compared to the K permeability P_K or the Cl permeability P_{Cl}. In the former case the resting potential would be determined mainly by the diffusion of K^+ ions, whereas in the latter case it would be essentially a chloride diffusion potential. These two possibilities may be distinguished by recording the membrane potential in solutions of varying ionic composition. **Fig. 6**. shows the result of such an experiment on a squid giant axon, in which the extracellular K^+ concentration was changed between 1.3 and 470 mM. Throughout the experiment the sum of extracellular K^+ and Na^+ concentrations was kept constant at 470 mM. The half-logarithmic representation reveals a good fit of the measured values E by the K diffusion potential $E_K = RT/F\ln([K]_0/400\text{mM})$ above $[K]_0$ = 30 mM. However, at lower extracellular K^+ concentrations the data significantly deviate from the "Nernst slope". With the Goldman equation (12.49) a satisfactory fit of the measured resting potential is possible for the whole range of $[K]_0$ values, the interrupted curve in Fig. 12.34 corresponds to the permeability ratios $P_K:P_{Na}:P_{Cl}$= 1:0.04:0.05. Hence the resting potential in squid giant axon is mainly governed by the potassium permeability of the axon membrane, whereas P_{Na} and P_{CL} are small in comparison with P_K.

Similar studies were performed on other cells to explore the permeability ratios in the resting state. Like in squid giant axons a prevailing K permeability was found in many other preparations. However, in frog skeletal muscle the Cl permeability is the dominant resting permeability. Thus the permeability ratios determined for one cell

may be following.

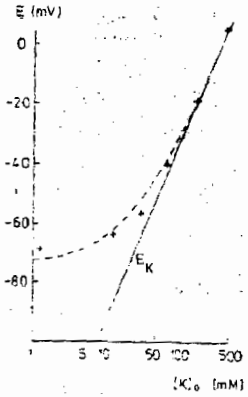


Fig.6. Dependence of the resting potential £ in squid giant axon on the extracellular K^+ concentration $[K]_0$. Analysis with the assumptions: E=—64mV for $[K]_0$=13mM and $[Cl]_0$ = 540 mM, $[Na]_i$ = 50 mM, $[K]_i$ = 400 mM, $[Cl]_i$ = 90 mM, T= 20°C not be applied to other types of cells. In many cases (e.g.. in myelinated nerve fibers) the origin of the resting potential is still unknown.

I. Find synonyms to the following words.

space, to obtain, to determine, to reveal, data, to explore, to vary, to govern.

II. Read these sentences. Choose the meaning for the underlined words.

1. In the former case the resting potential would be determined mainly by the diffusion, of K^+ ions, whereas in the latter case it would be essentially a chloride diffusion potential.
2. The interrupted curve in this figure corresponds to the permeability ratios.
3. Throughout the experiment the sum of extracellular K^+ and Na^+ concentrations was kept constant at 470 mM.
4. The data significantly deviate from the "Nernst slope".
5. Answer the following questions. Discuss your answer with a partner.
6. What are the possibilities which may be distinguished by recording the membrane potential in solutions of varying ionic composition?
7. What does Fig. 2. show?
8. What is the resting potential in squid giant axon governed by?
9. Similar studies were not performed on other cells, were they?
10. May the permeability ratios determined for one cell not e applied to other types of cells?

Text 20. **Contributions of Electrogenic Ion Pumps to the Membrane Potential**

It was explained above that a passive diffusion of cations and anions through the plasma membrane finally would abolish any concentration difference between the cytoplasm and the extracellular medium. This equalization is prevented by active transport processes, by which ions are transported against their concentration gradient under the consumption of metabolic energy. Membrane components participating in active transport are denoted as "ion pumps". They not only stabilize the ion concentrations in the outside and inside solutions but they may also contribute to the membrane potential, if their activity leads to a charge displacement across the membrane. An example of such an electrogenic ion pump is the active transport of Na^+ and K^+ ions, which is coupled in many membranes and occurs with the stoichiometry $3Na^+$:$2K^+$. Thus the pump transports more Na^+ ions from the cytoplasm into the extracellular solution than K^+ ions in the reverse direction. In this way the potential of the cell interior becomes more negative, hence part of the resting potential could originate from the activity of electrogenic ion pumps. However, this contribution is difficult to estimate since the charge transport through the pump cannot easily be distinguished from passive ion fluxes. Blocking the Na-K pump in squid giant axons with strophanthidin reduces the amount of the resting potential only by 1-2 mV. Similar small changes of the resting potential were found in other preparations. This suggests that electrogenic ion pumps do not significantly contribute to the membrane potential.

I. Complete each space with the prepositions given below.

1. A passive diffusion of cations and anions ... the plasma membrane abolish any concentration difference ... the cytoplasm and the extracellular medium.
2. They also contribute ... the membrane potential, if their activity leads ... a charge displacement ... the membrane.
3. Part of the resting potential could originate ... the activity ... electrogenetic ion pumps.
4. Blocking the Na-K pump ... squid giant axons ... strophanthidin reduces the amount of the resting potential only ... 1-2 mV.
5. This equalization is prevented ... active transport processes.

by, to, across, between, by, to, with, from, through, of, in

II. Change the false statements so that they become true.

1. A passive diffusion of cations and anions through the plasma membrane increase any concentration difference between the cytoplasm and the extracellular medium.
2. Ion pumps upset the ion concentrations in the outside and inside solutions.
3. The pump transports less Na+ ions from the cytoplasm into the extracellular solution than K+ ions in the reverse direction.
4. The charge transport through the pump is readily distinguished from passive ion fluxes.
5. Releasing the Na-K pump in squid giant axons with strophanthidin increases the amount of the resting potential only by 1-2 mV.
6. Electrogenic ion pumps greatly contribute to the membrane potential.

III. Find antonyms to the following words.

to reduce, to find, passive, to abolish, to stabilize, coupled, extracellular, interior, similar.

IV. Answer the following questions. Work in pairs.

1. What functions do ion pumps perform?
2. Does the pump transport more Na+ ions from the cytoplasm into the extracellular solution than K+ ions reverse direction?
3. Is it easy to distinguish the charge transport through the pump from passive ion fluxes?
4. Electrogenic ion pumps contribute significantly to the membrane potential, don't they?

Text21. **Transport by Diffusion. Transport by "Simple" Diffusion**

In this section we will consider transport processes which can be characterized by straight coefficients L_{ii} representing fluxes of components i induced by their conjugate forces, either chemical or electrochemical potential differences. The connection between a flux and its driving force can also be described by a permeability coefficient P_i, which is not so dependent on concentration as L_{ii}. The magnitude of the permeability coefficient alone can give no information about the molecular mechanism of permeation. Such information can only be extracted from comparison of the coefficients obtained upon variation of (1) the system parameters (concentrations of all components, pressure, temperature), (2) the properties of the

permeant particle (molecular weight, molecular geometry, chemical structure of side chains, charge, etc.) and (3) the properties of the membrane (lipid composition, protein side chain composition, lipid or protein charge, etc.). As will be shown, such studies allow a division of permeation processes into two groups, which are called "simple" diffusion and "facilitated" diffusion.

a) *Nonelectrolytes*

The most extensive permeability investigations up to now are those carried out by Collander and coworkers with algae. From these data, and from similar data from epithelial cells and red blood cells, we can conclude (1) that the cell membrane behaves as a lipid barrier, i.e.. that permeation is primarily determined by the same forces that determine the partition between lipid and water, and (2) that the cell membrane acts as a diffusion barrier, which lets large molecules pass less easily than small molecules.

These results can be explained easily by a simple diffusion model in which permeation is divided into three separate steps: (1) passage of a particle from the exterior solution into the hydrophobic membrane phase. (2) diffusion through the membrane and (3) emergence from the membrane phase into the other exterior solution. We assume that steps (1) and (3) are not rate determining, so that the surfaces of the membrane phase are always in local partition equilibrium with the exterior solutions. We can then write

$$\tilde{c}_{io} = K_i c_i' \qquad and \qquad \tilde{c}_{i\delta} = K_i c_i''. \tag{13}$$

where $\tilde{c}_{io}$ *and* $\tilde{c}_{i\delta}$ are the concentrations of i in the membrane surface, at $x = 0$ and $x = \delta$, and K_i is the partition coefficient. If we assume further that the diffusion flux of substance i through the membrane obeys Fick's first law, just as it does in an extended solution, then in the steady state we would have

$$\frac{j_i}{A} = \frac{\tilde{D}_i}{\delta}\left(\tilde{c}_{io} - \tilde{c}_{i\delta}\right), \tag{14}$$

where A is the membrane area and $\tilde{D}_i$ the diffusion coefficient of i in the membrane phase. This coefficient should be proportional to a negative power of the molecular weight M_i, just as in an extended solution:

$$\tilde{D}_i = f\frac{1}{M_i^{\beta}}. \tag{15}$$

Substituting **Eqs. (13)** into **Eq. (14)** we obtain

$$\frac{J_i}{A} = \frac{K_i \tilde{D}_i}{\delta}\left(c_i' - c_i''\right) \tag{16}$$

and thus

$$P_i = \frac{K_i \tilde{D}_i}{\delta}. \tag{17}$$

According to this model we should thus expect the permeability to increase with the membrane/water partition coefficient, and due to Eq. (15), to decrease with increasing molecular weight. The partition coefficients for membrane water are not known for natural membranes, of course. We know that the cell membrane consists primarily of lipids, however, and since the partition pattern varies only slightly in different lipids and lipid solvents, we can safely assume that the K_i for olive oil/water will give a good approximation of the situation at the membrane surfaces. Little is known about the dependence of the diffusion coefficient in lipids on molecular weight. In aqueous solutions the exponent β in Eq. (15) lies between 1/2 and 1/3.

The partition coefficient K_i is a measure of the difference of the molar free energy (Gibbs standard energy G,°) of a substance i in solution in two different phases. In partition equilibrium we must have

$$\mu_{iw} = \mu_{il} \tag{18}$$

where the indices w and l refer to the aqueous and nonaqueous phases and the index i indicates the test substance. If we separate the chemical potential into the concentration-dependent term $RT \ln c_i$ and the standard potential μ_i^o this equation becomes

$$\mu_{iw}^o + RT\,ln\,c_{iw} = \mu_{il}^o + RT\,ln\,c_{il}$$

and thus

$$\mu_{iw}^o - \mu_{il}^o = RT\,ln\frac{c_{il}}{c_{iw}} = RT\,ln\,K_i. \tag{19}$$

The difference $\mu_{iw}^0 - \mu_{il}^o$ between the standard potentials is identical with the difference between the partial molar free energy (Gibbs standard energy) in the two phases, $G_{iw}^o - G_{il}^o$. Values of G_{iw}^0 are known for dilute aqueous solutions of many substances from vapor pressure or solubility measurements. If such data are compared for a series of molecules in which only one group α (OH or CH_2, for example) is substituted or inserted at a time, G_{iw}^0 is found to change by a nearly constant, specific amount $\Delta G_{\alpha w}^0$. Similar regularity, in the form of a change by a nearly constant factor ε_x is found for the partition coefficient. With the help of **Eq.(19)** it is possible to derive approximate values of the contributions of each group α to the free energy change $(\Delta G_\alpha^0)_{w\to l}$ for the transfer of one mole of substance i from water into the lipid phase. $\left(\Delta G_\alpha^0\right)_{w\to l}$ is positive for all α except CH_2, i.e., the

addition or substitution of any other group reduces the lipid solubility and thus the permeability but the addition of CH_2 has the opposite effect. The fact that the values of ΔG^0_{cw}, (again with the exception of CH_2 groups) are larger than the values of ΔG^0_{al} indicates that the molecular interaction forces between water and dissolved substances are greater than those between lipids or membranes and substances dissolved therein. This implies that the basic pattern of permeability is determined primarily by the physical and chemical characteristics of the individual components in aqueous solution and only secondarily by the properties of the membrane. The general trends in permeability of cell membranes of completely different origin (algae, red blood cells, epithelial cells) are indeed nearly the same.

The thermodynamic data express the difference in strength of the molecular interaction forces in the different phases. In aqueous solution mainly hydrogen bonding with water molecules is involved, whereas in the lipid phase van der Waals forces and London dispersion forces are dominant. In the molecular perspective one can thus say that the greater the capacity of a molecule for forming hydrogen bonds, the lower will be its lipid solubility and its permeability through biological membranes. The introduction of an OH group, accordingly, which can act as an H donor or acceptor, produces the largest negative value of ΔG^0_{cw} and results in the sharpest drop in permeability.

There are important exceptions to this general trend in the permeability of nonelectrolytes:

1. Small hydrophilic molecules such as H_2O, and in many membranes urea and other amides diffuse more easily than expected from the discussion above. These exceptions indicate the presence of hydrophilic passageways, channels or pores which can be traversed only by small molecules.

2. Branched molecules penetrate membranes more slowly than unbranched isomers, even though the G^0_{cw}, values are more positive for the branched species so that one would expect K_i to increase. This result can be explained by the fact that a membrane, in contrast to a homogeneous lipid phase, has an ordered bilayer structure.

3. For numerous substances such as sugars there are special transport mechanisms which can raise the permeability very selectively by orders of magnitude. In this case we speak of "facilitated diffusion" as discussed in the next section.

b) *Electrolytes*

It is doubtful that simple diffusion plays a significant role in the transport of inorganic ions through cell membranes. The interaction forces between ions and

water are much stronger than for nonelectrolytes. We must thus assume that electrolytes do not penetrate into the lipid phase of the membrane in sufficient quantities to generate a measurable ion flux. Lipid bilayers have indeed very high electrical resistance, and can therefore scarcely be permeable to ions. The fact that the electrical resistance of cell membranes, in contrast, is orders of magnitude lower suggests that cell membranes have specific permeation aids for inorganic ions. For organic ions with π electrons, on the other hand, such as tetraphenyl borate or thiocyanate, lipid bilayers and cell membranes are easily permeable.

Ion transport by simple diffusion is found in epithelial membranes with terminal bars which are not completely closed, as in the proximal tubules of the kidney, the small intestine and the gall bladder. In traversing the terminal bars a substance need not overcome a continuous lipid barrier, because the cell membranes of adjacent cells approach each other only along a narrow strip with points of contact resembling "spot welding". The permeation behavior of the terminal bars of the proximal tubules of the kidney is similar to that of ion exchange membranes. It appears to be determined mainly by the dimensions of the interstices of the protein mesh and by a small excess of fixed negative charges.

I. Read these sentences from the chapter. Give the definition of the underlined words and word combinations and expression English in your mother tongue.

1 We will consider transport processes which can be characterized by straight coefficients L_{ii} representing fluxes of components and induced by their conjugate forces.

2. Such information can be extracted from comparison of the coefficients.

3. We can conclude that the cell membrane behaves as a lipid barrier.

4. The surface of the membrane phase are always in local partition equilibrium with the exterior solutions.

5. We can safely assume that the K_i for olive oil / water will give a good approximation of the situation at the membrane surfaces.

6. Values of G^0_{iw} are known for dilute aqueous solutions of many substances from vapor pressure or solubility measurements.

7. Lipid bilayers can scarcely be permeable to ions.

8. In traversing the terminal bars a substance need not overcome a continuous lipid barrier.

II. Mark the statements T ***if they are true or*** F ***if they are false.***

1. The most important investigations of permeability have been carried out by

Collander and coworkers with rats.

2. Due to its specific properties, the cell membrane lets large molecules pass less easily than small molecules.

3. According to a simple diffusion model we see the permeability disappear with the membrane / water partition coefficient.

4. The partition coefficient for membrane water are well known for natural membranes.

5. In aqueous solution mainly oxygen bonding with water molecules is involved.

6. The greater the capacity of a molecule for forming hydrogen bonds, the lower will be its lipid solubility and its permeability through biological membranes.

7. Simple diffusion certainly plays a significant role in the transport of inorganic ions through cell membranes.

8. The cell membranes of adjacent cells come nearer to each other with points of contact resembling 'spot welding'.

III. Skim the text, answer the following questions, then compare your answers with your partners.

1. What processes are considered in this chapter?
2. Describe the way in which the information about the molecular mechanism of permeation can be extracted.
3. What conclusion can be drawn on the basis of the data obtained by Collander and coworkers with algae?
4. What steps is permeation divided into?
5. When should we expect the permeability to increase and decrease?
6. Why does the partition patterns vary only slightly in different lipids and lipid solvents?
7. What values can be derived with the help of Equation (19) ?
8. How is the difference in strength of the molecular interaction forces expressed by the thermodynamic data?
9. Are there any exceptions to the general trend in the permeability of nonelectrolytes?
10. Does simple diffusion play a significant role in the transport of inorganic ions through cell membranes?
11. Are membranes easily permeable for organic ions?
12. Where can ion transport by simple diffusion be found?

IV. Write a brief summary on this chapter.

Text 22. **Transport by Facilitated Diffusion**

a) *Non-Electrolytes*

If the uptake of sugars by red blood cells is studied, one finds much higher transport rates for some sugars, such as D-glucose, whereas other sugars which hardly differ in structure or physical properties, such as L-glucose, do not attain comparably high transport rates.

The array of results shows that there must be a specific transport system in the membrane which recognizes individual sugar molecules and expedites their passage through the membrane. The prominent characteristics of this transport system led quite early to the formulation of the carrier model, described above, which succeeds in accounting for the phenomena listed here. This model, illustrated in **Fig.7** postulates the existence of specific enzyme molecules within the membrane which selectively bind sugar molecules at one side of the membrane, traverse the membrane, release the sugar at the other side of the membrane, and finally return without a load to the initial side. We limit outselves here to the most important observations derived from the explicit model:

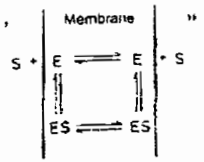


Fig. 7. Simple carrier model of transport of substrate S through a membrane by a diffusible carrier E

1. In agreement with experiment the carrier model exhibits only *passive* transport, and not active transport. Sugar transport ($J_i \neq 0$) is contingent upon a nonzero sugar concentration difference.

2. When $c_i' \neq 0$ *and* $c_i'' = 0$ then $J_i = \dfrac{\overline{P c_E} c_i'}{K_m + c_i'}$ **(20)**

which can account for the *saturation* behavior. Equation **(20)** is formally identical with the Michaelis-Menten kinetics of enzyme reactions, which is normally written as

$$V = \frac{V_{max} \cdot S}{K_m + S}, \qquad \textbf{(21)}$$

where V is the production rate, V_{max} the maximum production rate (corresponding

to Pc_E above), K_m is the Michaelis constant and S the substrate concentration.

3. Under the assumption that the specific activity of the enzyme-substrate complex at both sides of the membrane is the same as the specific activity of the substrate in the adjacent exterior phases, and that K and P do not differ for the tracer and for the unlabeled component, and assuming the conditions specified earlier we obtain (for the description of the tracer flux J_* of i in the presence of the unlabeled component 0)

$$J_* = P\bar{c}_E \frac{c_*(K + c_0'' - c_*'') - c_*''(K + c_0' + c_*')}{(K + c_0' + c_*')(K + c_0'' + c_*'')} \qquad (23)$$

For the case $c_*' > 0$, $c_*'' = 0$ and $c_0' > 0$, $c_0'' = 0$ this can be approximated by

$$J_* = P\bar{c}_E \frac{c_*'}{K + c_0' + c_*''}, \qquad (24)$$

This tracer flux will be inhibited by a concentration difference of the unlabeled component having the same direction as that of the tracer, or even by the presence of the unlabeled component without a concentration difference.

4. If the tracer is in equilibrium and a concentration difference is introduced for the unlabeled component, so that $c'_* = c''_* = c_*$ and $c_0' > c_0''$, then we find

$$J_* = P\bar{c}_E \frac{c_*(c_0'' - c_0'')}{(K + c_0' + c_*)(K + c_0'' + c_*)}. \qquad (25)$$

In this case the tracer flows against the flux of the unlabeled component (note c_0''-c_0' in the numerator) and we have *countertransport*. In addition the phenomenon of *irons-stimulation* can also be derived theoretically.

The simple carrier model thus is seen to account very well, at least qualitatively, for the principal characteristics of sugar transport observed in erythrocyte membranes. These include (1) the passive nature of the transport, (2) the saturation kinetics, (3) the existence of negative tracer coupling coefficients, which can lead to an overestimate of sugar permeability determined from tracer measurements and which can induce the phenomena of cis-inhibition, trans-stimulation and counter-transport of the labeled substance due to the unlabeled substance, and (4) the existence of negative cross coefficients for two different sugars which can evoke analogous phenomena of cis-inhibition, trans-stimulation and countertransport. The existence of a *diffusible* carrier, as required by the model, is thus indicated but by no means proven. Indeed, if one considers the size of the molecule which would be necessary for transporting a relatively large sugar molecule across the membrane,

then a freely diffusible carrier molecule is quite unlikely. On the other hand, our mathematical description is consistent with any other translocation process which can be approximated with first order reaction kinetics. Instead of diffusion of a whole carrier molecule the process might consist of a tilt or rotation of a binding site on a transport protein, or a conformation change of part of a pore, so that the binding site is accessible only from either the cis or trans side.

Transport mechanisms with similar characteristics are very widespread in living organisms. They are found in nearly all plasma-cell membranes and in bacterial cell membranes. In addition to sugar transport mechanisms there are similar ones for amino acids, such as on the interstitial side of kidney and intestinal cells and for a large number of other substances, such as short-chain fatty acids. Attempts to isolate such transport systems from the membrane material have been only partly successful. In bacteria a fresh synthesis of some transport systems can be induced by substrate in the exterior phase. With the help of radioactive labelling techniques proteins could be isolated which bind specifically to the substrate used to induce the synthesis. These proteins can be obtained from gram-negative bacteria, for example, where they are found in the periplasmic space between the plasma membrane and the bacterial wall and are extruded to the outside upon osmotic shock (brief reduction of the osmotic concentration in the exterior phase). Although it is certain that binding proteins are involved in transport, they seem to represent only a part of the transport system: it has been observed that even after removal of the binding proteins transport continues, though with a reduced affinity.

b) *Facilitated Diffusion of Water*

Since the water permeability of many cell membranes is just about the same as the water permeability of synthetic lipid bilayers, we can assume that water transport through cell membranes can proceed as simple diffusion through the lipid phase. On the other hand, there is ample evidence for the existence of special water-conducting pores. Many cells, such as the cells of the distal kidney tubules and the urinary bladder or frog skin, can change their water permeability by a factor of ten or more within a few minutes upon hormonal stimulation. The increased water permeability is accompanied by the appearance of new membrane particles in the luminal cell wall which are visible' in freeze-fracture electron micrographs as small clusters of protein particles. They seem to represent membrane channels or pores which selectively facilitate the passage of water. The transport mechanism is not yet understood in detail mainly as a result of technical problems. In contrast to the investigations of glucose transport discussed above, the water fluxes are so great that in the unstirred layers on either side of the membrane significant concentration profiles of the probe

substances, (such as HTO or D_2O) develop so that the barrier properties of the membrane are masked by diffusion delay in the unstirred layers.

I. Give synonyms to the following words.

rate, to attain, prominent, to account for, to postulate, explicit, to exhibit, to consider, to attempt, affinity, to proceed, to facilitate.

II. Use the following word combinations in the sentences of your own.

high transport rates; carrier model; negative tracer coupling coefficient; sugar permeability; relatively large sugar molecule; freely diffusible carrier molecule; bacterial cell membrane; short-chain fatty acids; radioactive labeling techniques; diffusion delay.

III. Make sentences using the word given below. If necessary, put the verbs in the proper form.

1) Hardly, other, to differ, in, sugars, or, properties, in, structure, physical.
2) Model, the, this, specific, molecules, to postulate, existence, of, enzyme.
3) Carrier, the, model, simple, for, characteristics, to account, principal, transport, of, sugar.
4) To isolate, systems, such, transport, at tempts, to be, successful, from, material, membrane, partly, only, the.
5) Certain, proteins, to be involved, it, to be, in, binding, transport.
6) Not, in, the, mechanism, yet, to understand, transport, detail.

IV. Answer the following questions.

1. What are transport rates for such sugars as D-glucose and L-glucose?
2. Describe the most important observations given in Eq. (20), (21), (22), (23), (24).
3. How does the simple carrier model account for the principal characteristics of sugar transport observed in erythrocyte membranes? What are these characteristics?
4. Is the existence of a diffusible carrier proven?
5. Where can transport mechanisms with similar characteristics be found?
6. Attempts to isolate such transport systems from the membrane material have been quite successful, haven't they?
7. Do binding proteins represent the whole transport system?
8. What assumption can be made on the basis of our knowledge of the water permeability?

9. Can cells change their water permeability upon hormonal stimulation?
10. What process do membrane channels or pores facilitate?
11. Why are the barrier properties of the membrane masked by a diffusion delay in the unstirred layers?

IV. Give a precise summary of the text.

Part II
Photobiophisics

Text 1. Energy Transfer

A very important photophysical process is the transfer of electronic energy from a primarily excited molecule D* (donor) to an acceptor molecule A which then undergoes a "sensitized" physical reaction, such as luminescence from A*, or a chemical reaction:

$$D + h\nu_D + A \rightarrow D^* + A \rightarrow D + A^* \rightarrow \text{reaction.}$$

Either D* and A* may occur in their first excited singlet, $|S_1\rangle$, or triplet states, $|T_1\rangle$. In condensed phases, higher states are unessential for this kind of process because of their very fast (within picoseconds) deactivation via internal conversion and vibrational relaxation. A fast removal of energy from D^* can protect this molecule from undesired photoreactions. Several mechanisms provide for the energy transfer $D^* \rightarrow A$:

a) The "Trivial" Process: Emission of a Photon by D* and Reabsorption by A,

$$D^* + A \rightarrow D + h\nu_D + A \rightarrow D + A^*$$

The probability of this process depends on R^{-2}, where R is the donor-acceptor distance, and also on their mutual orientation. The observed rate is not influenced by solvent viscosity and sample geometry. If $A \neq D$, the lifetime of D* is not affected by the presence of A.

b) Radiationless Energy Transfer $D^* \rightarrow A$

Quantum theory tells us that the transition probability between two states ψ_1 and ψ_2 of a system is governed by the square of the matrix element

$$\beta = \langle \psi_1 | \tilde{L} | \psi_2 \rangle \qquad (26)$$

with the operator $\tilde{L}$ representing the interaction which causes the transition; **Eq. (26)** is called a "resonance integral".

For our purpose, let (D*··· A) and (D··· A*) represent two different states of an electronically excited donor-acceptor pair which may be separated by some solvent molecules. It will be convenient to distinguish several classes of transfer mechanisms:

1. coherent transfer: the phases of the excitation of a number of molecules are correlated (this case is known in particular from molecular crystals, with A=D);

2. incoherent transfer: an initial phase relation among the excited D* molecules, produced by coherent excitation, is lost rapidly (on the time scale of energy transfer). In solution, dephasing occurs within a few picoseconds; it is caused by random interactions (collisions) with the surroundings.

3. "Very weak coupling case": $|\beta| < \Delta E$, where ΔE is the amplitude of energy fluctuations in the matrix, for example from thermally excited phonons. In this case, D* undergoes many internal vibrations before transmitting its electronic energy to A, whereas in

4. the "weak coupling case", $|\beta| \approx \Delta E$, only a few vibrational periods elapse.

5. In the "strong coupling case", finally, the excitation energy can no longer be thought of as being localized either on D* or A*. Contrary to cases (3) and (4), the absorption spectrum of the mixture (D··· A)is now very different from a superposition of the pure D and A spectra

The mechanism of incoherent transfer with weak coupling has been studied extensively by Th. Forster since 1946. We confine our description to this case, since it has been emphasized by R. S. Knox that this is the only one of relevance in photobiology.

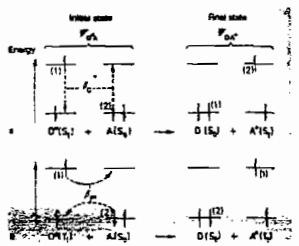


Fig. 1. Mechanisms of energy transfer according to **Eqs. (27)** and **(29)**

To develop the main aspects of the theory we choose the most simple MO model: let D=A, and the relevant electron configurations in either molecule, i.e. S_0, S_1 and T_1, be represented by two molecular orbitals and two electrons. This situation is illustrated in **Fig. 1.** Let only two run electrons, labeled "1" and "2", sparated by r_{12}, be involved in the process.

The significant parts of the antisymmetrized total wave function of the system (D···A)* before (Ψ_{D^*A}) and after (Ψ_{DA^*}) the transfer then read

$$\Psi_{D^*A} = \frac{1}{\sqrt{2}}\left[\psi_{D^*}(1)\psi_A(2) - \psi_{D^*}(2)\psi_A(1)\right] \qquad \textbf{(27a)}$$

and

$$\Psi_{DA^*} = \frac{1}{\sqrt{2}}\left[\psi_D(1)\psi_{A^*}(2) - \psi_D(2)\psi_{A^*}(1)\right] \qquad \textbf{(27b)}$$

With $\tilde{L}$ of **Eq. (26)** representing the Coulomb interaction between electrons 1 and 2, $\tilde{L} = 1/r_{12}$ in atomic units, from **Eq. (26)** we obtain

$$\beta = \beta_C + \beta_{ex}, \qquad \textbf{(28)}$$

where β is the sum of the matrix elements

$$\beta_C = \left\langle \psi_{D^*}(1)\psi_A(2)\left|\frac{1}{r_{12}}\right|\psi_D(1)\psi_{A^*}(2)\right\rangle \qquad \textbf{(29)}$$

"Coulomb term"

and

$$\beta_C = \left\langle \psi_{D^*}(1)\psi_A(2)\left|\frac{1}{r_{12}}\right|\psi_D(2)\psi_{A^*}(1)\right\rangle$$

(29b)

"exchange term".

[In the strong coupling case, the functions **(27)** are not an adequate basis, and the partition of **Eq. (28)** becomes meaningless]. The two different mechanisms represented by β_c and β_{ex} are indicated in **Fig. 4a** and **b**, respectively.

Spin selection rules demand conservation of total spin in the entire system (A··· D)* and forbid transitions $T_1 \leftrightarrow S_0$ within one of the molecules alone. Hence, only the exchange mechanism β_{ex} contributes to triplet (D)→triplet (A) energy transfer, whereas for singlet-singlet transfer both paths are open. They differ significantly in their range: β_{ex} is effective only if there is spatial overlap between the wave functions of D* and A. Because of the exponential decay of the wave functions with distance, exchange occurs only during contact (or collision) of D* with A, typically for $R<0.5$ nm.

The Coulomb term β_c, is of much greater importance. It can cause considerable coupling over distances as great as 10 nm. In a multipole expansion of r_{12}^{-1} in **Eq. (29a)**, the dipole-dipole term is in general dominant for not too small values of R:

$$\beta_C \approx \beta_{dipole-dipole} \approx \boldsymbol{M}_A \boldsymbol{M}_D R^{-3} n^{-2} \qquad (30)$$

where the measurable parameters $\boldsymbol{M}_D$ and $\boldsymbol{M}_A$ are the electronic transition moments of (free) D and A respectively, n is the refractive index and n^2 the optical diclectric constant of the solvent matrix.

Only if $\boldsymbol{M}_D$ or $\boldsymbol{M}_A$=0 due to high molecular symmetry do contributions of higher moments become important, such as

$$\beta_{dipol-quadrupole} \infty R^{-4}, \quad or$$

$$\beta_{quadrupole-quadrupole} \infty R^{-5}.$$

For the cases considered here, Fermi's "golden rule" applies, and the transfer rate constant, $k_{D^*\to A}$, i.e. the probability per molecule and unit time for the energy exchange, is given by

$$k_{D^*\to A} = \frac{2\pi}{\hbar}|\beta|^2 \rho \qquad (31)$$

where $\hbar = h/2\pi$ and ρ is a measure for the density of interacting initial and final states of the real system.

Forster has defined a characteristic range R_0 of the coupling as the (mean) distance D*··· A for which deactivation of D* by emission of a photon (rate constant k_0) plus internal nonradiative relaxation (k_{nr}) have the same probability as has the transfer D*→A. R_0 is determined by measuring the dependence of the fluorescence intensity or decay time of D* on the concentration of A.

If there is only one acceptor at a fixed distance R interacting with each donor, an exponential decay of D* results from **Eq. (31)**. The R-dependance turns out to be

a) for exchange interaction

$$k_{D^*\to A} \approx \frac{1}{\tau_D} e^{-\gamma(R-R_0)}, \qquad (32a)$$

b) and for Coulomb interaction

$$k_{D^*\to A} \approx \frac{1}{\tau_D}\left(\frac{R_0}{R}\right)^S, \qquad (32b)$$

where τ_D is the fluorescence lifetime of D * in the absence of A, its inverse $\tau_D^{-1} = k_0 + k_{nr}$ the coefficient γ represents the spatial overlap of the D* and A **wave** functions, s=6 for dipole-dipole, s=8 for dipole-quadrupole, and s=10 for quadrupole-quadrupole coupling. In practice, R^{-6} (averaged) = n_A n_D (n_x : molecules X per **unit** volume).

For the most important dipole-dipole case, Forster has evaluated

$$R_0^6 = \frac{Ck^2\phi_D}{n^4} I. \qquad (33)$$

A fairly good value is

$$R_0 / \text{nm} \approx 0.735 (c_A^0)^{-1/3}.$$

With c_A^0 = "critical acceptor concentration" in moll^{-1}, at which the **D*** fluorescence in quenched to 50 %.

The quantities entering q **(33)** are: n, refractive index of solvent; K an orientational factor, K^2=2/3 for very fast rotational motion of D and A; ϕ_D fluorescence quantum yield of D in the absence of A; the constant C contains Einstein's transition coefficients and factors from units; I is an integral accounting for the energetic overlap of interacting states in D* and A; it is related to the factor ρ in **Eq. (31)** and may be evaluated from D*-luminescence and A-absorption spectra:

$$I = \int_0^\infty f_{D^*}(\tilde{\nu}) \varepsilon_A(\tilde{\nu}) \frac{d\tilde{\nu}}{\tilde{\nu}^4}$$

where $f_{D^*} = dn_e / d\tilde{\nu}$ is the number of luminescence quanta of D **per** wavenumber interval, the so-called quantum emission spectrum of D, normalized **to** $\int_0^\infty f_{D^*}(\tilde{\nu}) d\tilde{\nu} = 1$, $f_{D^*}(\tilde{\nu}) d\tilde{\nu}$, is the probability that D* emits a photon in the range $\tilde{\nu}$, $\tilde{\nu} + d\tilde{\nu}$, and ε_A is the extinction coefficient of A in 1 mol $^{-1}$ cm $^{-1}$ as defined in **Eq.** (5.4). Only spectral overlap of f_D and ε_A contributes to I, as illustrated in **Fig. 2.**

From the normalization of f_D it follows that R_0 should be independent of **the** magnitude of the transition moment $\boldsymbol{M}_D$ of the donor. Indeed, experimental R_0 **values** for triplet-singlet transfer are not significantly smaller than for singlet-singlet **transfer,** in contrast to the RO values for triplet-triplet transfer, where ε_A is extremely small.

We will now sketch the more general approach given by A. Blumen. Consider **a** "host" lattice of inert molecules with concentration c_H (molecules/volume). A few **of** the regular lattice sites are occupied by donors(c_D), other by acceptors (c_A). Let **us** first consider the case $c_D < c_A << c_H$. For one individual donor we then have

$$k_{D^*\to A} = \sum_i k_{D^*\to A_i}(R_i)$$

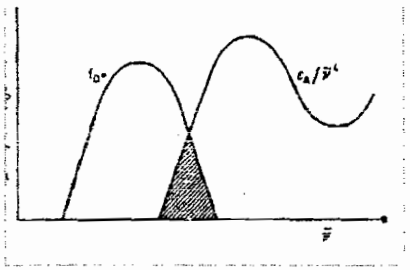


Fig. 2. Spectral overlap condition for Forster type energy transfer. The area under f_D is normalized to 1

The decay behaviour of the whole ensemble of donors is now no longer simple exponential but rather is given by

$$\tilde{\phi}(t) = exp[-t/\tau_D]\phi(t) \qquad (34)$$

where

$$\phi(t) = \prod_i (1 - c_{A/c})\{1 - exp[-k_{D^*\to A_i}(R_i)t]\} \qquad (35)$$

and $c=c_H + c_A+c_D$. For longer times and with $c_A \le c/10$,

$$\phi_{\Delta,s}(t) = exp[-Ac_A t^{\Delta/s}] \qquad (35a)$$

for multipole interaction, and

$$\phi_{\Delta,ex}(t) = exp[-Ac_A g_\Delta(Bt)] \qquad (35b)$$

for exchange interaction.

The constants A and B are determined by γ, R_0 and τ_D (see **Eq. 32a**); Δ is the dimensionality of the lattice, (2 for monolayers, 3 for solutions), s characterizes the multipole character, as in **Eq. (32b)**, and g is an analytical function:

$$g_\Delta(z) = \Delta\int_0^\infty x^{\Delta-1}(1 - exp[-ze^{-x}])dx$$

$$= \Delta! \sum_{j=1}^{\infty} \frac{(-1)^{j-1} z^j}{j!\, j^\Delta}$$

For the most common case dipole-dipole interaction ($s = 6$) between oriented D and A in solution ($\Delta=3$), **Eqs. (34 and 35a)** lead to Forster's famous decay law:

$$\phi(t) = exp[-Ac_A\sqrt{t}]. \qquad (36)$$

Deviations from **Eq. (36)** may be caused by superposition of different mechanisms and by special lattice structures. For short t after an exciting light pulse, the decay function is more complex. At large values of t, experimental difficulties arise from the low fluorescence intensity.

Finally let us consider the case $C_A<C_D<C_H$, i.e. a high excess donor concentration. In most practical cases, only a small fraction of the donors will be excited at a time, $C_{D^*} << C_D$. In this case, energy is interchanged among a number of donors before falling into an acceptor trap. This "indirect transfer" cannot be described in closed form. The excitation moves as an "exciton" through the donor lattice, the coupling to the acceptors changing with each jump. Yet in many cases a fairly quasi-exponential decay is observed, which may be described by

$$k_{D^*\to A} \propto c_A c_D^{\frac{s}{\Delta}-1}.$$

In all the models considered above, diffusion has not been taken into account. If the distance R_i change during the lifetime of D*, the rate constants depend markedly on viscosity, and hence on temperature.

I. Read these sentences from the paper. Give the meaning for the underlined words; use them in sentences of your own.

1. It will be convenient to distinguish several classes of transfer mechanisms.
2. The excitation energy can no longer be thought of as being localized either on D* or A*.
3. We confine our description to this case, since it has been emphasized that this is the only one of relevance in photobiology.
4. We will now sketch the more general approach given by A. Blumen.
5. At large values of t, experimental difficulties arise from the low fluorescence intensity.

II. Complete each space with a word or phrase from the text.

1. A fast removal of energy from D* can protect this molecule from … … .
2. The observed rate is not influenced by … … and sample geometry.
3. Only the exchange mechanism B_{ex} contributes to triplet (D) → triplet (A) energy transfer, whereas for … … … both paths are open.
4. β_{ex} is effective only if there is … … between the wave functions of D* and A.
5. Forster has defined a characteristic range R_o of the coupling as the (…) … D*.
6. Consider a "host" lattice of … … with concentration C_h (molecules / volume).
7. For short t after … … …, the decay function is more complex.

8. The excitation moves as an "exciton" through the ...,

solvent viscosity, singlet-singlet transfer, donor lattice, undesired photoreactions, spatial overlap, (mean) distance, inert molecules, exciting light pulse.

III. Choose antonyms for the following words.

internal, relaxation, to separate, adequate, meaningless, expansion, decay, complex (adj.), effective, rapidly, random (adj.)

IV. Skim the text, answer the following questions, compare your answers with your partners.

1. What important photophysical process is dealt with in this chapter?
2. What kind of mechanisms provide for the energy transfer D*→A? What are their classes?
3. Who has studied the mechanisms of incoherent transfer with weak coupling?
4. What do spin selection rules demand and forbid?
5. The Coulomb term B_c is of much importance, isn't it? If so, prove it.
6. Does Fermi's "golden rule" apply for the cases considered in this chapter?
7. In what way has Foster defined a characteristic range R_o of the coupling?
8. Describe an approach suggested by A. Blumen.
9. What conclusions can be made if we consider the case $C_a<C_d<C_h$?

V. Write a complete summary of this text.

Text 2. **Delayed Fluorescence**

In some cases one observes, besides a "prompt" $S_1 \rightarrow S_0$ fluorescence and a slowly decaying $T_1 \rightarrow S_0$ phosphorescence, a third type of emission, with the spectrum of the fluorescence but a longer decay time. Several mechanisms can account for this effect.

(a) In the *"E-type"* delayed fluorescence, excited molecules in the long-lived triplet state T_1 are thermally activated to S_1. Their $S_1 \rightarrow S_0$ has an emission component which decays with the phosphorescence decay time τ_P; the intensity I_E depends strongly on the temperature T. Plotting $\log(I_E/I_{Phosph.})$ over $1/T$ yields a straight line with negative slope. E-*type* fluorescence is favored by a small T_1-S_1, energy gap.

(b) The *"P-type"* mechanism corresponds triplet-triplet annihilation. If two excited molecules in their long-lived T_1 state collide, their energies may be concentrated on one of them, lifting it to its S_1 state and leaving the donor in the ground state. Since

one S_1 molecule results from two excited molecules, the P-type fluorescence intensity is proportional to the square of the exciting light intensity. The rate of formation of S_1 molecules is diffusion-controlled ; the decay time is $1/2\,\tau_P$. A special case is that of triplet excitons moving around in a molecular crystal. Both of these processes, E-type and P-type, can be sensitized, i.e. the triplet states involved can be populated by energy transfer from primary excited donor molecules.

(c) If, in a condensed phase, a molecule D is adjacent to another molecule or a crystal site which has some electron affinity, an electron may be moved to this "trap" as a consequence of exciting D, say to state S_2, by a quantum with energy far below the ionization energy of free D. Recombination of a thermally released electron from the trap with D^+ sometimes results in excited D* (S_1) or D* (T_1) with subsequent luminescence emission. The decay function depends on the nature of the traps and is, in general, not a simple exponential.

I. Find these words in the text. Match the words with their definitions.

1. phosphorescence
2. annihilation
3. primary
4. affinity
5. trap
6. prompt
7. decaying
8. adjacent

a) loosing power
b) done. given, without delay
c) lying near, next to
d) device for catching animals. etc.
e) the giving out of light without burning
f) complete destruction
g) leading in time, order or development
h) close connection, structural resemblance, relationship

II. Fill in the gaps with appropriate prepositions.

1. This mechanism accounts ... this reaction.
2. An emission component decays ... the phosphorescence decay time.
3. E-type fluorescence is favored ... a small $T_1 \rightarrow S_1$ energy gap.
4. One S_1 molecule results ... two excited molecules.

5. The triplet states can be populated ... energy transfer ... primary excited donor molecules.
6. A molecule D is adjacent ... another molecule or a crystal site.
7. Recombination of a thermally released electron from the trap with D^+ sometimes results ... excited D* (S_1) or D* (T_1) ... subsequent luminescence emission.

III. Answer the questions and discuss your answer with a partner.

1. What is the third type of emission?
2. What can this type of emission be accounted for?
3. What can happen to E-type and P-type processes?
4. What does recombination of a thermally released electron from the trap with D* sometimes result in?

Text 3. Primary Photochemical Reactions

In an electronically excited state such as S_1 or T_1, a molecule has a charge distribution different from its groundstate. This involves a change in chemical reactivity and in properties which include: bond lengths and equilibrium conformation; acidity, basicity and dipole moment; ionization potential, electron affinity and redox potential.

In the MO-model, different electronic states are described by different MO-occupation schemes (more exactly: electron configurations); mainly the "homo's" and the "lemo's" are strongly involved. They generally have different symmetries, and the "principle of conservation of orbital symmetry", known as the Woodward-Hoffmann rules, teaches us why reactions starting from the thermally, i.e. vibrationally, excited ground state follow other paths than photochemical reactions from excited electronic states. Because of the weak interaction of electronic and nuclear motions, an electronically, excited molecule, is not simply a "hot" molecule.

More sophisticated models also take into account steric effects and intermolecular interactions, especially hydrogen bonds. In condensed matrices, molecular vibrations relax very fast, within a few picoseconds or some hundred vibrational periods. Therefore, photochemical and luminescence processes usually start from vibrationless S_1 or T_1 states. This is not the case for gases at low pressures. In polar solvents such as water, polar and charged reaction products, and also solvated electrons, are stabilized; in dilute gases, photoradicals often start a reaction chain.

The most relevant photobiological processes are photosynthesis and the visual process. But gas phase photochemistry in the atmosphere especially in the ionosphere, is also of great importance for life on earth: photoproducts, mainly O_3 and O, protect the earth's surface against damaging ultraviolet rays; on the other hand, a host of pollution products, including NO, are photochemically produced from chemical emissions.

In the following, only a few very elementary reactions are chosen to illustrate the most important primary photoreactions. Laser pulse spectroscopy with time resolution down to a few picoseconds is the most direct method for probing single reaction steps.

I. Find synonyms for the words from the text.

property, configuration, path, sophisticated, to take into account, therefore, to start, relevant, primary.

II. Are the following statements true or false? Say why.

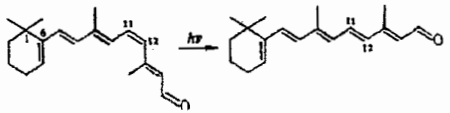
1. In an electronically excited state such as S_1 or T_1, a molecule has a charge distribution similar to its groundstate.
2. The principle of conservation of orbital symmetry teaches us why reactions starting from the thermally excited ground state follow other paths than photochemical reactions from excited electronic states.
3. Excited molecule is a "hot" molecule.
4. In condensed matrices, molecular vibrations rise very fast.
5. Gas photochemistry in the atmosphere is of no importance for life on earth.
6. The earth's surface needs no protection against ultraviolet rays.

III. Answer the following questions. Discuss your answers in pairs.

1. What changes in chemical reactivity and properties are discussed in this chapter?
2. What is "the principle of conservation of orbital symmetry"?
3. Why do photochemical and luminescence processes usually start from vibrationless S1 or T1 states?
4. Why is gas phase photochemistry in the atmosphere of great importance for life on earth?

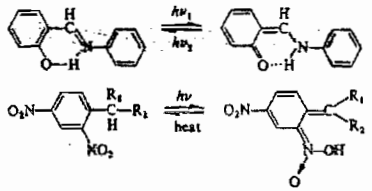
Text 4. **Monomolecular Photoreactions**

α) cis~trans Photoisomerization. The primary step hi the visual process is the rotation around the C_{12}-C_{13} bond of protein-bound retinene:



neoretinene b, dark form all-trans retinene

β) Phototautomerism. Photochromic effects, i.e.. reversible photoreactions with change of color, can be caused by an intramolecular proton shift. This is observed with crystals and solid solutions of some anils and nitro compounds:



γ) Photorearrangement. Quite a wide variety of photoreactions are undergone by different ketones, including steroids such as ergosterol. Depending on electronic structure, conformation, and matrix influece, these reactions may result in: formation, enlargement contraction, or cleavage of ring structures; in enolization, substituent displacement, or intramolecular addition. Photo-induced valence isomerization is of importance in the vitamin D series. T_1 *(nπ*)* excited ketones also very effectively abstract hydrogen atoms from alcohols.

δ) Photodissociation, Photolysis. By the mechanism of "internal conversion", electronic energy is transformed into vibrational energy in the excited molecule. If several vibrational quanta accumulate in a certain (σ) bond, the molecule may dissociate. This step is followed by a rearrangement or a bimolecular reaction. In "homolytic cleavage", two radicals or a diradical are formed; "heterocleavage" results in an ion pair or a zwitterion. Examples are: elimination of CO from ketones, of N_2 from azo compounds, of reactive singlet-O_2 from endoperoxides; ionic dissociation of cyanides and nitrites. A similar model explains the photochemically induced ligand exchange of transition metal complexes.

I. Make sentences using the word given below.

1. Proton, cause, shift, can, intermolecular, effects, photochromic.
2. May, in, these, ring, of, reactions, results, structures, cleavage.

3. Of, vitamin, photo-induced, importance, valence, is, isomerization, series, in, D, the.
4. Molecule, dissociate, the, if, may, accumulate, several, quanta, in, vibrational, certain, quanta, (σ) bond, a.
5. The, induced, exchange, a, model, explains, similar, photochemically, ligand, metal, complexes, of, transition.

II. Put the verbs in brackets in the appropriate form. Mind the Passive Voice.

1. Such effects (to cause) by an intramolecular proton shift.
2. A wide variety of photoreactions (to undergo) by different ketons.
3. In this way electronic energy (to transform) into vibrational energy.
4. This step (to follow) by a rearrangement.
5. The examples of this process (not to look into) by a group of our experts yet.
6. A similar model (to explain) by our professor before we (to start) our investigation.
7. Monomolecular Photoreactions (to discuss) from 3 till 5 p. m. yesterday.

II. ***Give a detailed oral description of the most important primary photoreactions.***

Text 5. **Magnetic Field Effects on Radical-Pair Reactions**

Let an orbital bonding together two parts of a molecule, A and B, be occupied by two electrons with antiparallel spins: A↓-↑B. When the bond is cleaved, the spin orientations will be conserved for a while: A↓···↑B. If the radical pair is trapped in a solvent cage, there is a high probability of "geminal re-encounter".

Now there is some probability of flipping an electron spin through electron-nuclear spin interaction. If this occurs for one of the radicals, say B˙, before A˙ and B˙ meet again (typically within $\tau \approx 1$ ns), recombination is prevented by the Pauli exclusion principle: two electrons occupying one MO must have different spins. In this case, A↓ and ↓B will diffuse apart and undergo other reactions. If, on the other hand, neither spin flips within time τ, geminal reaction competes with other reactions and so lowers their yield. A quantitative analysis shows that even weak magnetic fields, like the earth's field, markedly influence the spin flipping rate and hence the yield of (photochemical and other) radical reactions via spin selection rules, although the energetic effect of such weak Fields in negligible in comparison with mean

thermal energies, kT. The same mechanism is responsible for the "chemically induced dynamic nuclear polarization", CIDNP. It seems however, that biomagnetic effects have different causes.

I. Put in the missing words. Consult the text given above.

1. When the bond ..., the spin orientations ... for a while.
2. If flipping an electron spin ... for one of the radicals, recombination ... by the Pauli exclusion principle.
3. A↓ and B↓ ... apart and ... other reactions.
4. If neither spin ... within time τ, geminal reaction ... with other reactions and so ... their yield.
5. Even weak magnetic fields markedly ... the spin flipping rate.
6. The same mechanism ... for the "chemically induced dynamic nuclear polarization".

II. Give Ukrainian equivalents for the following word combinations.

solvent cage, electron-nuclear spin interaction, Pauli exclusion principle, spin flipping rate, spin selection rules, mean thermal energy, chemically induced dynamic nuclear polarization.

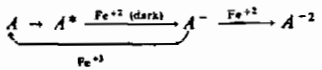
III. Answer the question to the text and discuss your answers in pairs.

1. What will happen if the radical pair is trapped in a solvent cage?
2. Does a quantitative analyses show any influence of weak magnetic fields on the spin flipping rate?

Text 6. Bimolecular Primary Reactions

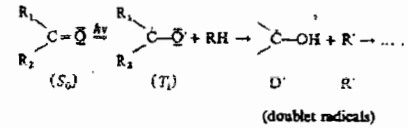
The yield of bimolecular reactions with optically excited molecules depends essentially on the lifetime of the excited state and on diffusion rates (viscosity). Most bimolecular photoreactions start from a T_1 state, because of its "metastability".

ε) Photoreduction. A number of organic dyes *(A,* electron acceptors), such as methylene blue, react photochemically with a reducing agent, such as Fe^{+2}, according to the scheme



ζ) Photoaddition. Quite a number of photoaddition reactions are known, often resulting in cyclic structures. Reactions of biological interest are, among others, photodimerization, and addition of water to pyrimidines which also may undergo photoreduction.

η) Hydrogen Abstraction. Aromatic ketones in their $T_1(n\pi^*)$ state, when this is the lowest excited state, dehydrate alcohols, cellulose (which becomes brittle), and other H-donors (RH) according to



(doublet radicals)

The $T_1(n\pi^*)$ state of aromatic ketones has a biradicallike electronic structure, with one electron localized essentially on the oxygen atom, in a nonbonding orbital, and the other in a π-MO delocalized over the aromatic skeleton. The H abstraction is followed by fast radical reactions of the doublet radicals D· and R·.

I. Match the following words with their definitions.

yield	being viscous
lifetime	substance used to give colour to
viscosity	substance producing an effect framework of à plan, theory
dye	amount produced
agent	duration of one's life
cellulose	structural issue that forms the chief part of all plants and trees
skeleton	an active power or cause

II. Answer the questions to the text.

1. What does the yield of bimolecular reactions with optically excited molecules depend on?
2. In what way do organic dyes react photochemically?
3. Which reactions may undergo photoreductions?
4. What is the H abstractions followed by?

III. Render the main ideas of the text in English orally.

Text 7. Spectral Sensitization

A sensitizer, S, is a photocatalyst. After absorption of a photon $h\nu_s$ it transfers its excitation energy to an acceptor A, which in turn may react chemically and which, by itself, will not absorb light in the same wavelength range as S does:

$$S + h\nu_s + A + B \rightarrow S^* + A + B \rightarrow S + A^* + B \rightarrow S + \text{products}$$

At the end of this cycle, S is restored and ready to act again. The most effective mechanisms are: (a) radiationless energy transfer, and (b) a redox reaction between S* and A. In the latter case, the sensitizer has to be regenerated by a further component of the system, such as O_2.

The only requirement for mechanism (a) to be possible is that the excitation energy of S* be equal to or higher than that of A*. This is not necessary for the primary step of (b); instead, the orbitals of S* and A which interchange an electron must have (approximately) the same energies with respect to a common ionization level for S and A, and the orbitals involved must overlap spatially. Therefore, process (b) depends strongly on the electronic and conformational constitution of S and A, whereas process (a) does not. Very effective sensitizers for triplet excitation of A via process (a) are found in the class of aromatic ketones, e. g. benzophenone with triplet energy $E(T_1 n\pi^*) \approx 3$ eV. Spectral sensitization of photographic materials and of redox reactions at electrodes follow mechanism (b).

I. Look through the following statements. Say whether they are true or false. Correct the false statements.

1. An acceptor A will absorb light by itself in the same wavelength range as a sensitizer S does.
2. In the later case, the sensitizer has to be regenerated by a further component of the system.
3. The excitation energy of S* must be lower than that of A* to make the mechanism (a) possible.
4. Process (b) does not depend on the electronic and conformational constitution of S and A.
5. Benzophenone with triplet energy $E(T_1 n\pi^*) \approx 3$ eV belongs to the class of aromatic ketones.
6. Spectral sensitization of photographic materials and of redox reactions as electrodes is followed mechanism (b).

II. Put in the missing prepositions and conjunctions.

1. ... absorption of a photon $h\nu_3$S it transfers its excitation energy ... an acceptor A, which ... turn may react chemically.
2. ... the end ... this cycle, S is restored.
3. They must have the same energies ... ... a common ionization level for S and A.
4. Effective sensitizers ... triplet excitation ... A ... process (a) are found ... the class ... aromatic ketones.

III. Answer the following questions. Discuss your answer in pairs.

1. Where does a photocatalyst transfer its excitation energy?
2. What happens to S at the end of the reactions?
3. What are the most effective mechanisms?
4. What requirement makes mechanism (a) possible?
5. Process (b) depends on the electronic and conformational constitution of S and A, doesn't it?
6. Where are effective sensitizers for triplet excitation of A via process (a) found?

Text 8. Photosensitized Oxygenation by Singlet O_2

O_2 is the most important of the few molecules with a triplet ground state. Spin-allowed energy transfer from an excited sensitizer (dye S) in its T_1-state, $^3D^*$, results in excited singlet oxygen, $^1O_2^*$,

$$^1S + h\nu_S + {}^3O_2 \rightarrow {}^1S^* + {}^3O_2 \rightarrow {}^3S^* + {}^3O_2 \rightarrow {}^1S + {}^1O_2^*$$

which is generally created in two different states: $^1\Delta_g$, with energy $E_1 = 0.96$ eV, and, in less abundances $^1\Sigma^+_g$ with $E_2 = 1.6$ eV. Both singlet states are metastable. $^1O_2^*$ reacts with aromatics and with cis-dienes yielding peroxides, and with olefins forming alcohols. Its role in the oxydative degradation of enzymes and nucleic acid: as well as in the generation of skin cancer is under current investigation.

I. Skim the text, answer the following questions, then compare your answers with your partner.

1. What role does O_2 play?
2. Both singlet states are metastable, aren't they?
3. What substances does $^1O_2^*$ react with?

II. Give the main idea of the text.

Text 9. **Photodynamic Effects**

Certain photoreactions cause alterations in biological systems which range from malign (such as a rash) up to deadly. In many cases a light-induced oxidation in the presence of O_2 is the essential step. "Dyes" from food (e.g., chlorophyll), from medication or from cosmetics (e. g. eosin, now forbidden) can act as sensitizers, as can metabolic products, such as hemoglobin, which have accumulated due to some regulatory defect. It is likely that a high luminescence quantum yield, indicating an essential lack of other deactivating mechanisms, favors photodynamic activity by creating singlet O_2. Effective but biochemically harmless energy acceptors, for example carotinoids, can act as preventive quenchers of this reaction.

I. Skim the text, answer the following questions, discuss your answers in pairs.

1. What alterations do certain photoreactions cause in biological systems?
2. Can "dyes" from food, medication or from cosmetics act as sensitizers?
3. How do carotinoids act?

II. Write a brief summary on the text.

Appendices

I.ABSTRACT

аннотация

к научной статье

1. This paper presents the results of an analysis of ... . Theoretical expressions for ... are presented. The ... that are resulting from ... have been identified in terms of ... .

1. ...Данная статья представляет результаты анализа ... . Представлены теоретические выражения для ... ., которые возникают в результате ..., определены с точки зрения ... .

* * * * *

2. In the present paper ... are applied to the investigation of ... . Particular attention is given to ... . Experimental results obtained in ... are presented. A new method for ... is described.

2. В данной статье применяются ... для исследования ... . Особое внимание уделяется ... . Представлены результаты эксперимента, полученные в ... . Описан новый метод ... .

* * * * *

3. The paper deals with ... . A description is given of ... . Results are given which ... . A method of ... is proposed. Conditions for .... are investigated on the basis of ... . were detected. In addition, possible reasons for ... are discussed.

3. Статья имеет дело с ... . Дано описание ... Приводятся результаты, которые ... . Предлагается метод ... . На основе ... исследуются условия ... . Были обнаружены ... . Кроме того, обсуждаются возможные причины ... .

*****

4. ... has been measured. It was found that ... . have been observed ... are discussed in detail. In contrast, ... has been found to be dependent on ... . The effects of ... have been studied. The results suggest that ... .

4. Было измерено ... . Было обнаружено, что ... . Наблюдались ... . Подробно обсуждаются ... . Напротив, обнаружено, что ... зависит от ... Изучено влияние ... . Результаты предполагают, что ... .

*****

5. ... is studied, a ... method is used. It appears, in particular, that ... Some peculiarities in ... were interpreted as arising from ... can be explained by ... and is attributed to ... .

5. Изучается ..., применяется ... метод. Оказывается, в частности, что ... . Некоторые особенности ... объяснялись как результат ... ... можно объяснить ..., и ... приписывается ... .

*****

6. It is shown that ... . First, ... Second, ... The possible ... are discussed. ... is considered in terms of (on the basis of ...). And the significance of ... is pointed out ... calculations are suggested.

6. Показано, что ... . Во-первых, ... Во-вторых, ... Обсуждаются возможные ... . рассматривается с точки зрения (на основе ...). Отмечается значение ... . Предложены ... вычисления.

*****

6. ... have been determined by ... method. Measurements were made of ... . On the basis of ..., ... has been calculated.

7. ... определены ... методом. Были сделаны измерения ... . На основе ... были вычислены ...

*****

It is assumed that ...	Предполагается, что ...
It is suggested that ...	Предполагается, что ...
It is shown that ...	Показано, что ...
It was found that ...	Было обнаружено, что ...
It was concluded that ...	Был сделан вывод, что ...
It has been established that ...	Установлено, что

*****

1. The subject of our investigation is ...	1. Тема нашего иследования...
2. The aim (task, purpose) of our research (work, experiment) is (was)	2. Целью (задачей) нашего исследования (работы эксперимента) было
— to investigate the properties of ...	— исследовать свойства ...
— to measure the value of ...	— измерить величину ...
— to obtain the data on ...	— получить данные по ...
— to prove that	— доказать, что ...
— to provide the evidence of	— привести доказательство о...
to analyse the information on	— проанализировать информацию по
—to determine the dependence of...on...	— определить зависимость ... от
3. In our investigation (experiment) the attempt was made (we tried)	3. В нашем исследовании (эксперименте) делалась попытка (мы пытались)
— to discover a new method of ...	— открыть новый метод ...

— to work out a new approach to …
— to find a new way of …
to study the peculiarities of …

— разработать новый подход к
— найти новый способ …
— изучить особенности …

4. The studies were directed (aimed) at
— developing a new method of …
— obtaining the reliable (additional) information on …
— proving the theory of …
— confirming the assumption
— solving the problem of …
— explaining the phenomenon

4. Исследования были направлены (нацелены) на …
— разработку нового метода …
— получение надежной (дополнительной) информации о
— доказательство теории …
— подтверждение предположения
— решение проблемы (задачи)
— объяснение явления

5. The problem (phenomenon property effect) under consideration (under study…)
— is of great importance for
— is of great interest to …

— has been treated by
— was studied in the course of (our experiment)

5. Рассматриваемая/исследуемая проблема (явление, свойство, влияние)
— является очень важным для
— представляет большой интерес для …
— была рассмотрена к-либо
— были изучены в ходе …

6.According to our theory (conception, assumption)

— the results depend on

6. В соответствии с нашей теорией (концепцией, предположением)
— результаты зависят от

(e.g. the conditions of …)
— the properties of … can be influenced by …
— the changes of … are caused by …
— this effect is due to …

(условий …)
— на свойства … может влиять

— изменения … вызваны

— это явление обусловлено

7. By means of (on the basis of) this method (experiment)
— the additional (exhaustive, reliable, detailed) information was obtained on
— the data were obtained on …
— has been calculated

7. Посредством (на основании) этого метода (эксперимента)
— была получен дополнительная (исчерпывающая, надежная, подробная) информация по …
— были получены данные по …
— было подсчитано

8. In the course of our research (experiment)
As a result of our research (experiment)

8. В ходе нашего исследования (эксперимента)
В результате нашего исследования (эксперимента)

— a new conception has been developed
— our theory has been proved
— the discovery has been made
— a new phenomenon has been discoved

— была разработана новая концепция
— была доказана наша теория
— было сделано открытие
— новое явление было открыто

9. We should take into consideration (emphasize analyse)
— the benefits of this approach

9. Нам следует принять во внимание (подчеркнуть, проанализировать)
— пользу этого подхода

— the advantages of our method
— the peculiarities of this theory
— the drawbacks of this method

10. We can rely on
— on this information,
— refer to these data
— take advantage of these findings
— make use of these results

11. These results (data, experiments) provide an evidence of
— the correctness of our theory (conception)
— the reliability of this method
— the advantages of this approach
— the importance of our idea

12.-There is good evidence that…

— this method of solving the problem of is reliable
— our way of treating this problem is true
— the process of … can be explained by…
— this phenomenon is due to …
— the properties of ... depend on …
— the changes of (in) …

— преимущество нашего метода
— особенности этой теории
— недостатки этого метода

10. Мы можем
— полагаться на эту информацию
— ссылаться на эти данные
— воспользоваться этими данными
— использовать эти результаты

11. Эти результаты (данные, эксперименты) свидетельствуют о
— правильности нашей теории (концепции)
— надежности этого метода
— преимуществах этого подхода
— важности нашей идеи

12. Есть веские основания полагать, что …
— этот метод решения задачи является надежным
— наш способ трактовки этой проблемы является верным
— процесс …можно обьяснить

— это явление обусловлено …
— свойства … зависят от…
— изменения чего-либо в …

are caused by …
— many factors influence this process

13. There is every reason to rely on the data obtained

— to conclude that …
— to assume that …

14. We can give arguments
— for this theory
— for our conception
— against the assumption that …

— against the idea of …

15. This proves (supports, confirms)
— the idea put forward in our paper
— the theory developed by …
— the assumption that …

16. From these studies (experiments) On the basis of these results (data)

— we arrived at some conclusions

вызваны …
— многие факторы влияют на этот процесс

13. Есть все основания
— полагаться на полученные данные
— сделать вывод о том, что…
— предположить, что…

14. Мы можем привести доводы
— в пользу этой теории
— в пользу нашей концепции
— против того предположения, что …
— против идеи …

15. Это доказывает (подтверждает)
— идею, выдвинутую в нашей статье
— теорию, разработанную …
— предположение о том, что …

16. Из этих исследований (в результате экспериментов) На основании этих результатов (данных) мы пришли к некоторым вывода
— мы сделали выводы

17. The results of our investigation (experiment)	17. Результаты нашего исследования (эксперимента)
— prove (confirm) that our assumption was true	— доказывают (подтверждают), что наше предположение было верно
— can be used in …	— могут использоваться в …
— are of great importance for …	— имеют большое значение для …
— were published in …	— были опубликованы в …
18. The importance / significance of	18. Важность / значение
— this discovery	— этого открытия
— idea	— идеи
— theory,	— теории
— method,	— метода
— these results	— этих результатов
— data	— данных
— conclusions	— выводов
— can hardly be overestimated	— трудно переоценит

II.ЧТЕНИЕ МАТЕМАТИЧЕСКИХ, ХИМИЧЕСКИХ СИМВОЛОВ И ФОРМУЛ НА АНГЛИЙСКОМ ЯЗЫКЕ

\+ **plus** 1. плюс; 2. знак плюс; 3. положительная величина; 4. добавочный, дополнительный

— **minus** 1. минус; без; 2. знак минус; 3. отрицательная величина; отрицательный

. **point** точка (в десятичных дробях)

… and so on и так далее

/ (или :, или —) division sign знак деления

= 1. sign of equality знак равенства; 2. equals, (is) equal to равняется, равно

≈ approximately equal приблизительно равно

> greater than больше (чем)

< less than меньше (чем

∞ 1. infinity бесконечность, бесконечно удаленная точка; 2. infinite бесконечный

$\sqrt{}$ **square root (out) of** корень квадратный из

$\sqrt[3]{}$ **cube root (out) of** корень кубический из

$\sqrt[n]{}$ **root (out) of** корень п-й степени

[ ] brackets, square brackets pi. квадратные скобки

( ) parentheses, round brackets pi. круглые скобки

{ } braces фигурные скобки

° degree градус

' minute минута

" 1. second секунда; 2. inch дюйм

ā a barred «а» с черточкой

$\tilde{a}$ a tilded «a» с волнистой черточкой

a* a star «a» со звездочкой

a′ a prime «э» прим

a″ a second prime или a double prime, «a» два штриха

a‴ a third prime или a triple prime «a» три штриха

c_m c sub т или c, m-th «c» «м» («с» с индексом «м»)

a_1' first prime

a_2'' a second, second prime

a_m a sub m или a, m-th

b_c' prime, sub c или b sub c, prime

ż first derivative of z первая производная «z»

In logarithm natural натуральный логарифм

f(x) или φ(x) function of *x* функция от «x»

Σ summation знак суммирования

dx differential of дифференциал «x»

dy/dx derivative of *y* with respect to *x* производная «y» по «x»

$\mathbf{d^2y/dx^2}$ second derivative of *y* with respect to *x* вторая производная «y» по «x»

$\mathbf{d^ny/dx^n}$ *n*-th derivative of *y* with respect to *x* — n-я производная «y» по «x»

y/x derivative of *y* with respect to *x* производная «y» по «x»

∫ integral of интеграл от

∫ f(x)dx integral of a function of *x* over *dx* интеграл от функции *f(x)* по *dx*

$\int_n^m$ integral between limits *n* and *m* интеграл в пределах от «n» до «m»

|x| absolute value of *x* абсолютное значение «x»

& and и

! factorial факториал

% per cent процент

, comma запятая

. full stop точка (знак препинания)

— dash тире

§ section mark параграф

* asterisk звездочка, знак выноски

DIVISION ДЕЛЕНИЕ

divide делить(ся); подразделять(ся)

dividend делимое

divisor делитель; дивизор

quotient частное, отношение

the unknown искомое

remainder остаток, остаточный член; разность

: (или / или —) **division sign** знак деления, **divided by**, **over** деленное на

Примеры:

a : b = c *a* divided by *b* is equal to *c*

$\frac{a+b}{a-b} = \frac{c+d}{c-d}$ *a* plus *b* over *a* minus *b* is equal to *c* plus *a* over *c* minus *d*

FRACTIONS ДРОБИ

COMMON FRACTIONS ПРОСТЫЕ ДРОБИ

numerator числитель

denominator знаменатель

integer целое число

cardinal numbers количественные числительные

ordinal numbers порядковые числительные

nought нуль (главным образом в математике)

zero нуль (главным образом на шкалах)

decimal десятичный

В простых дробях числитель выражается количественным числителем, а знаменатель — порядковым.

Если числитель больше единицы, то знаменатель принимает окончание s.

В смешанном числе целое число читается как количественное числительное, а дробь присоединяется к нему союзом and.

Примеры

$\frac{1}{2}$ One half (a half)

$\frac{1}{3}$ One third (a third)

$\frac{2}{7}$ Two sevenths

$3\frac{1}{2}$ Three and a half

$4\frac{1}{7}$ Four and one seventh

$4\frac{5}{8}$ Four and five eighths

INVOLUTION ВОЗВЕДЕНИЕ В СТЕПЕНЬ

power степень, показатель степени
raise to a power возвышать в степень
exponent показатель
square квадрат; квадратный; возводить в квадрат
cube куб; кубический; возводить в куб
even четный; **even form** четная степень

Примеры:

3^2 Three squared (Three square)
Three (raised) to the second power
Three to the power two
The second power of three

5^3 Five cubed
Five cube
Five (raised) to the third power
Five to the power three
The third power of five
The cube of five

10^7 Ten to the seventh power

10^{-7} Ten to the minus seventh power

Z^{-10} Z to the minus tenth power
Z to the minus tenth

EVOLUTION ИЗВЛЕЧЕНИЕ КОРНЯ

root корень
extract извлекать; extract the root of (out of) извлекать корень из
$\sqrt{}$ **radical sign** знак корня

Примеры:

$\sqrt{4} = 2$
The square root out of four is (equals) two

$\sqrt{a}$ The square root of a

$\sqrt[3]{a}$ The cube root of a a^2

$\sqrt[5]{a^2}$ The fifth root out of a square

$\sqrt[5]{a^7}$ The fifth root out of a to the power seven

PROPORTION ПРОПОРЦИЯ

term член, терм
expression выражение
extremes pi. крайние члены пропорции
means pi. средние члены пропорции
mean среднее, среднее значение; средний
proportional пропорциональный; член пропорции
direct непосредственный, прямой
directly прямо, непосредственно
inverse обратный, инверсный
inversely обратно; обратно пропорционально
vary меняться; **vary directly (inversely) as** изменяться прямо (обратно) пропорционально
constant постоянная (величина); константа α varies as изменяется

Примеры:

$a : b = c : d$	a is to b as c is to d
$x \ \alpha y$	x varies directly as y
	x is directly proportional to y
$x = k/y$	x varies inversely as y
	x is inversely proportional to y

EQUATION УРАВНЕНИЕ

formula формула
value величина; значение

Пример:

$(a + b)(a - b) = a^2 - b^2$ «The product of the sum and difference of two quantities is equal to the difference of their squares»

ГРЕЧЕСКИЙ АЛФАВИТ

Αα alpha [' ælfə] альфа
Ββ beta ['beitə, 'bi:tə] бета
Γγ gamma ['gæmə] гамма
Δδ delta ['deltə] дельта
Εε epsilon ['epsi'lon] эпсилон
Ζζ (d)zeta ['zeitə, 'zi:tə] дзета
Ηη eta ['eitə, 'i:tə] эта

Θϑ theta ['Θeitə, 'Θi:tə] тэта
Ιι jota [ai'outə] йота
Κκ kappa ['kæpə] каппа
Λλ lambda ['læmbdə] ламбда
Μμ mu [mju:] ми (мю)
Νν nu [nju:] ни (ню)
Ξξ xi [ksi:] кси
Οο omikron [ou'maikrən] омикрон
Ππ pi [pi] пи
Ρρ rho [rou] ро
Σσ sigma ['sigmə] сигма
Ττ tau [tau] тау
Υυ upsilon ['ju:psi'lon] ипсилон
Φφ phi ['fi:j фи
Χχ chi ['hi:] хи
Ψψ psi ['psi:] пси
Ωω omega [ou'megə, ou'mi:gə] омега

ТАБЛИЦА ХИМИЧЕСКИХ ЭЛЕМЕНТОВ

Ac Actinium [æk'tiniəm] Актиний
Ag Argentum [a:'dgentəm]=silver ['silv] Серебро
Al Aluminium [ælju'minjəm] Алюминий
Am Americium [ə'me'risiəm] Америций
Ar, A Argon ['a:gən] Аргон
As Arsenic ['a:snik] Мышьяк
At Astatium [s'teitiəm] Астат(ин)
Au Aurum ['o:rəm] = Gold [gould] Золото
B Boron ['bo:ron] Бор
Ba Barium ['beriəm] Барий
Be Beryllium [bə'riliəm] Бериллий
Bi Bismuth ['bizməΘ] Висмут
Bk Berkelium [bə':keiljəm] Берк(е)лий
Br Bromine ['broumi:n] Бром
C Carbon ['ka:bən] Углерод
Ca Calcium ['kælsiəm] Кальций
Cd Cadmium ['kædmiəm] Кадмий
Ce Cerium ['si riəm] Церий
Cf Californium [kæli'fo:injəm] Калифорний
Cl Chlorine ['klo:ri:n] Хлор
Cm Curium ['kju:riəm] Кюрий
Co Cobalt [ko'bo:lt] Кобальт

Cr Chromium ['kroumiəm] = Chrome ['kroum] Хром
Cs C(a)esium ['si:zi m] Цезий
Cu Cuprum ['kju:pr m] = Copper ['кор] Медь
Dy Dysprosium [dis'prouziəm] Диспрозий
Em Emanation [emə'neiʃən] Эманация
Er Erbium [:biəm] Эрбий
Es Einsteinium [ain'stainiəm] Эйнштейний
Eu Europium [juə'roupiəm] Европий
F Fluorine ['fluəri:n] Фтор
Fe Ferrum ['ferəm] = Iron ['aiən] Железо
Fm Fermium ['fə:mjəm] Фермий
Fr Francium ['frænsiəm] Франций
Ga Gallium ['gæliəm] Галлий
Gd Gadolinium [gædə'liniəm] Гадолиний
Ge Germanium [dgə:'meiniəm] Германий
H Hydrogen ['haidrəgən] Водород
He Helium ['hi:ljəm] Гелий
Hf Hafnium ['ha:fniəm] Гафний
Hg Hydrargyrum ['hai'dra:girəm] = Mercury ['mə:kjuri] Ртуть
Ho Holmium ['houlmiəm] Гольмий
In Indium ['indiəm] Индий
Ir Iridium [ai'ri:diəm] Иридий
J, I Iodine ['aiədi:n] Йод
K Kalium ['кaliəm] = Potassium [pə'tesjəm] Калий
Kr Krypton ['kripton] Криптон
La Lanthanum ['lænΘənəm] Лантан
Lw Lawrentium [lo:'rentiəm] Лоренций
Li Lithium ['liΘiəm] Литий
Lu Lutecium [lu'ti:ʃiəm] Лютеций
Md Mendelevium [mendə'li:viəm] Менделевий
Mg Magnesium [mæŋg'ni: ziəm] Магний
Mn Manganese [mægə'ni:z] Марганец
Mo Molybdenum [mə'libdinəm] Молибден
N Nitrogen ['naitrədgən] Азот
Na Natrum ['nætriəm] = Sodium ['soudjəm] Натрий
Nb Niobium [nai'oubiəm] Ниобий
Nd Neodymium [ni 'dimiəm] Неодим(ий)
Ne Neon ['ni:on] Неон
Ni Nickel ['nikl] Никель
No Nobelium [nou'bi:liəm] Нобелий
Np Neptunium [nep'tju:niəm] Нептуний
O Oxygen ['oksidgən] Кислород

Os Osmium ['ozmiəm] Осмий
P Phosphorus ['fosfərəs] Фосфор
Pa Prot(o)actinium ['prout æk'tiniəm] Протактиний
Pb Plumbum ['plʌmbəm] Lead [led] Свинец
Pd Palladium [pə'leidiəm] Палладий
Pm Promethium [prə'mi:Θiəm] Прометий
Pr Praseodymium [prezi 'dimiəm] Празеодим
Pt Platinum ['plætinəm] Платина
Pu Plutonium [plu:'tounjəm] Плутоний
Ra Radium ['reidiəm] Радий
Re Rhenium ['ri:niəm] Рений
Rh Rhodium ['roudiəm] Родий
Rz Ruthenium [ru:'Θiniəm] Рутений
S Sulphur ['sʌlfə] Сера
Sb Stibium ['stibjəm] = Antimony ['æntiməni] Сурьма
Sc Scandium ['skændjəm] Скандий
Se Selenium [si'linjəm] Селен
Si Silicon ['silikən] Кремний
Sm, Sa Samarium [sə'ma:riəm] Самарий
Sn Stannum ['stænəm] = Tin [tin] Олово
Sr Strontium ['stronʃiəm] Стронций
Ta Tantalum ['tæntələm] Тантал
Tb Terbium [tə:biəm] Тербий
Tc Technetium [tek'niʃiəm] Технеций
Te Tellurium [te'lju:riəm] Теллур
Th Thorium ['Θo:riəm] Торий
Ti Titanium [tai'teiniəm] Титан
Tl Thallium ['Θæliəm] Таллий
Tu, Tm Thullium ['Θju:liəm] Тулий
U Uranium [ju'reiniəm] Уран
V Vanadium [v 'neidiəm] Ванадий
W Wolfram(ium) ['wolfrəm]=Tungsten['tʌŋstən] Вольфрам
Xe Xenon [zenon] Ксенон
Y, Yt Yttrium ['itriəm] Иттрий
Yb Ytterbium [i't :biəm] Иттербий
Zn Zinc(um), Zink [ziŋk] Цинк
Zr Zirconium [z 'kouniəm] Цирконий

ФОРМУЛЫ

Латинские буквы, входящие в уравнения или обозначающие названия химических элементов, читаются английские буквы в алфавите.

ФОРМУЛЫ МАТЕМАТИЧЕСКИХ УРАВНЕНИЙ

«Two plus x plus the square root of four plus x squared

$2 + x + \sqrt{4 + x^2} = 10$ is equal to ten»

$M = R_1 x - P_1(x - a_1) - P_2 (x - a_2)$ «M is equal to R sub one multiplied by x minus P sub one round brackets opened, x minus a sub one, round brackets closed, minus P sub two, round brackets opened, x minus a sub two, round brackets closed»

$E = \frac{\frac{p}{a}}{\frac{o}{l}} = \frac{pl}{ae}$ « E is equal to the ratio of p devided by a to o divided by I is equal to the ratio of the product pi devided by the product ae »

$\sqrt{\frac{F_1 + A}{2xa}}$ «The square root (out) of F first plus A over (divided by) two xa double prime »

$\int \frac{dx}{\sqrt{a^2 - x^2}}$ «Integral of dx over (divided by) the square rootout of a square minus x square »

$\frac{d}{dx} \int_{x_0}^{x} Xdx$

«d over (divided by) dx of the integral from x sub o to x of capital Xdx»

$\Delta S = S_2 - S_1 = \int_{T_1}^{T_2} \frac{\Delta q}{T}$

«Delta S is equal to S sub two minus S sub one is equal to integral from T sub one to T sub two of delta q over (divided by) T»

$$A_v = \frac{\mu\omega m \omega^2 L^2}{r_p\left[\omega^2 m^2 + R_2\left(R_1 + \frac{\omega^2 L^2}{r_p}\right)\right]}$$

«A y-th is equal to μ omega m omega square L square (divided) by rp-th square brackets opened omega square m square plus R second round brackets opened R first plus omega square L square (divided) by r_p-th round and square brackets closed »

ФОРМУЛЫ ХИМИЧЕСКИХ СОЕДИНЕНИЙ И УРАВНЕНИЙ ХИМИЧЕСКИХ РЕАКЦИЙ

Цифра перед обозначением элемента указывает число молекул и читается следующим образом: $2MnO_2$ ['tu: 'molikju:lz v 'em 'en 'ou 'tu:]

Знаки + и — стоящие в левом верхнем углу, обозначают положительную и отрицательную валентность иона:

H^+ — hydrogen ion или univalent positive hydrogen ion
Cu^{++} — divalent positive cuprum ion
Al^{+++} — trivalent positive aluminium ion
Cl^- — negativc chlorine ion или negative univalent chlorine ion
Знак — *или* : обозначает одну связь и не читается:
Знак = *или* : : обозначает две связи и также не читастся:
Знак + читается: plus, and или together with
Знак = читается: give или form
Знак → читается: give, pass over to или lead to
Знак ← читается: forms или is formed from

III. Biomembrane Models

(Summary)

Experimental results of the last decade have conclusively demonstrated that the bulk of the lipid in practically all membranes exists in the form of a bilayer, as was first postulated by Gorter and Grendel in 1925. Earlier and present-day bilayer models differ mainly in the placement of membrane protein. From the early work of Davson and Danielli (1935) to the unit membrane hypothesis of Robertson (1959) the membrane proteins were generally thought to form continuous layers on the surfaces of the lipid bilayer and to interact mainly with the hydrophilic lipid head groups. In 1971 Singer pointed out that such an arrangement had conceptual difficulties and could not explain many experimental results. He proposed instead an arrangement in which the proteins penetrated deeply into or through the lipid bilayer to form a "mosaic". Such proteins are amphiphilic and held in the-bilayer through hydrophobic interactions . In 1972 Singer and Nicolson extended this model to the "fluid mosaic" model, depicting the lipid phase of the membrane essentially as a two-dimensional liquid, in which both protein and lipid molecules could diffuse freely.

Many experimental results have since born out the main features of the fluid mosaic model. Freeze-fracture electron microscopy has directly demonstrated the presence of proteins in the interior of nearly all membranes. Spectroscopic and microscopic techniques have confirmed the diffusion of both lipids and proteins in the plane of the membrane. The fluid mosaic model has met with rapid and general acceptance and proved to be of considerable heuristic value. It is now also obvious that at least in its original form the model neglected the substantial asymmetry of membrane lipids, the role of peripheral proteins, the restrictions placed on the mobility of membrane proteins, and the role of surface oligosaccharides.

Because membranes function as permeability barriers, general models have emphasized the features which serve this function. It is clear that the lipid bilayer forms the basic permeability barrier for water-soluble ions and molecules. It is modified predominantly by the insertion of proteins which allow membranes to carry out their other functions, such as transport, signal transduction, and energy transduction. General models have not yet included information about these special features. However, more and more functional units such as ion pumps, transport proteins, and hormone receptors, are being isolated and their structures explored. It is possible that common features will be found and models for such functions incorporated into the general model.

It is also clear that membranes are dynamic structures. Synthesis of membrane components, their assembly and turnover may hold the key to a number of still poorly understood observations. These include the differentiation of membranes within the cell and the asymmetry of lipids across individual membranes. Finally, the interaction of membranes with other cell components, especially the cytoskeleton. or with other membranes, especially in the processes of endo- and exocytosis, needs to be considered in future membrane models.

CONTENTS

Навчальне видання

Воскобойникова Лариса Володимирівна

Гаташ Сергій Васильович

Лешньова Наталія Олександрівна

Практикуємо читання текстів з біофізики

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